engineering proceedings

MDPI

Proceeding Paper

Sustainable Supply Chain Management for Plastic Manufacturing in Small- and Medium-Sized Enterprises Using MCDA Method †

Hansraj Tundiya, Mohammad Ali Palsaniya, Nishi Panchal, Pranav Topre, Yash Bhavsar and Sharfuddin Ahmed Khan *

Industrial Systems Engineering, University of Regina, Regina, SK S4S 0A2, Canada; htn631@uregina.ca (H.T.); mps728@uregina.ca (M.A.P.); npm245@uregina.ca (N.P.); pst077@uregina.ca (P.T.); ydb570@uregina.ca (Y.B.)

* Correspondence: sharfuddin.khan@uregina.ca; Tel.: +1-306-585-4705

† Presented at the 1st International Conference on Industrial, Manufacturing, and Process Engineering (ICIMP-2024), Regina, Canada, 27–29 June 2024.

Abstract: This study analyzed the operational environment of supply chains involved in the production of eco-friendly plastics, with a particular emphasis on small- and medium-sized businesses worldwide. Qualitative research methods were used to highlight the significance of extended producer responsibility (EPR) regulations and strong recycling programs for the sustainability of small- and medium-sized enterprises (SMEs). Also, this study looked at international regulations affecting the implementation of circular economy strategies and the difficulties in creating sustainable supply chains. It concluded that waste reduction, effective supply chain management, and sustainable practices are crucial aspects of a more effective and sustainable global plastic-manufacturing sector. This research highlighted the significance of government policies in SME revival and used Multiple-Criteria Decision Analysis (MCDA) to help SMEs adopt sustainable supply chain practices that act as a catalyst for industry reform.

Keywords: sustainable practices; circular economy; sustainable supply chain methods; extended producer responsibility; clean manufacturing

Citation: Tundiya, H.; Palsaniya, M.A.; Panchal, N.; Topre, P.; Bhavsar, Y.; Khan, S.A. Sustainable Supply Chain Management for Plastic Manufacturing in Small- and Medium-Sized Enterprises Using MCDA Method. *Eng. Proc.* **2024**, *76*, 84. https://doi.org/10.3390/engproc2024076084

Academic Editors: Golam Kabir, Mohammad Khondoker and Hussameldin Ibrahim

Published: 19 November 2024

1. Introduction

In the context of the global industrial landscape, sustainability is viewed as an adjunct to a working cycle that is already productive. Organizations need to strategically manage economic, social, and environmental challenges by seamlessly integrating sustainability into their functional components [1]. Plastics are known to have a greater environmental impact than most other products. Owing to their wide range of uses, industries find it difficult to implement a standard procedure to stop environmental damage after plastic products are used for the first time [2,3]. By dividing plastics into groups according to the value chain, businesses adopted a recycling and circular economy philosophy. The disparity between the Sustainable Goals and the supply chain is made clear by the fact that while 65% of brands and retailers have reduced their use of virgin plastic, International Commitment members have only seen a slight decrease (−0.1%) since 2018, even though the top performers have achieved a 13% decrease, which has been countered by increased usage among some larger firms [4]. Businesses that prioritize good environmental practices, social responsibility, and ethical governance are not just doing the right thing, they are also setting themselves up for long-term success. The U.S. National Recycling Goal aims for a 50% recycling rate by 2030 by challenging SMEs with compliance costs, as well as offering market opportunities through sustainable innovations [5]. This ESG trifecta represents the key to building a responsible and sustainable future for both companies and society. For instance, formerly dependent on virgin polyester, Mohawk now uses only recycled plastic bottles for carpets—roughly 6.6 million bottles per year—which saves the company $4.3 million in landfill, haul-away, and wastewater treatment costs.

This study investigated breaking away from the conventional "take-make-dispose" mindset. To establish sustainable practices in plastic production, this research explored extended producer responsibility (EPR) with an emphasis on post-consumer stages, encasing waste management, raw materials, value chain, and regulation. Driven by the worldwide issue of plastic pollution, particularly from small- and medium-sized enterprises (SMEs), this research aimed to identify and address practical challenges while advocating for a paradigm shift toward circular economy ideas, sustainable supply chains, and diligent waste disposal without altering the life cycles of products.

1.1. Background

Businesses have implemented mitigation strategies to lower carbon emissions, set achievable targets, and use these measures as a competitive advantage because customers value a company's reputation. In a survey conducted by Aspen Technology Inc. among 340 business professionals globally, where Asia accounted for 19% and India for 11% of the responses based on the poll, asset-intensive businesses supported current efforts to reduce carbon emissions and encouraged sustainable behavior strongly [6]. The plastic manufacturing industry's capacity to maintain its competitiveness and to adjust changing working conditions is what is essentially meant by sustainability in this context.

1.2. Sustainable Supply Change Management

The study of sustainable supply chain management (SSCM) is the outcome of an attempt to integrate the triple bottom line concept to current SCM practices, which include sustainability as a crucial component [7]. SSCM aims to accomplish objectives from the economic, environmental, and social dimensions of sustainable development, which entails managing capital, information, and material flows, in addition to fostering collaboration between businesses along the supply chain. These requirements are derived from customers and stakeholders [8]. SSCM is "the planning, transparent integration and accomplishment of an organization's social, environmental, and financial objectives in the systematic coordination of key interorganizational business processes for improving the individual and its supply chain's long-term economic performance" [9].

2. Literature Review

The main goal of this research was to create a comprehensive review of the research undertaken on sustainable supply chains, specifically aimed at sustainable supply chains in the plastic industry. A range of methodological techniques were employed to examine the problem and arrive at a definitive conclusion through an analysis of the types of publications and literature using various search engines. PRISMA empowers comprehensive research reviews by ensuring all relevant studies are identified, assessed, and transparently reported, minimizing bias. This standardized approach enables replication and reduces potential biases, ultimately contributing to high-quality systematic reviews with robust findings [10]. Guided by the PRISMA methodology, our literature search yielded 131 initial articles (Figure 1). The analysis revealed a thriving plastic industry that was actively pursuing sustainability via diverse means, like extended producer responsibility and circular economy models. Focusing on papers from 2019–2023, to obtain an overview of the pre-COVID-19 and post-COVID-19 scenario, we shortlisted 41 for a detailed review, ultimately selecting 27 for the in-depth analysis. This process unveiled the methods and challenges employed by plastic industries, particularly SMEs, in their quest for sustainability [11].

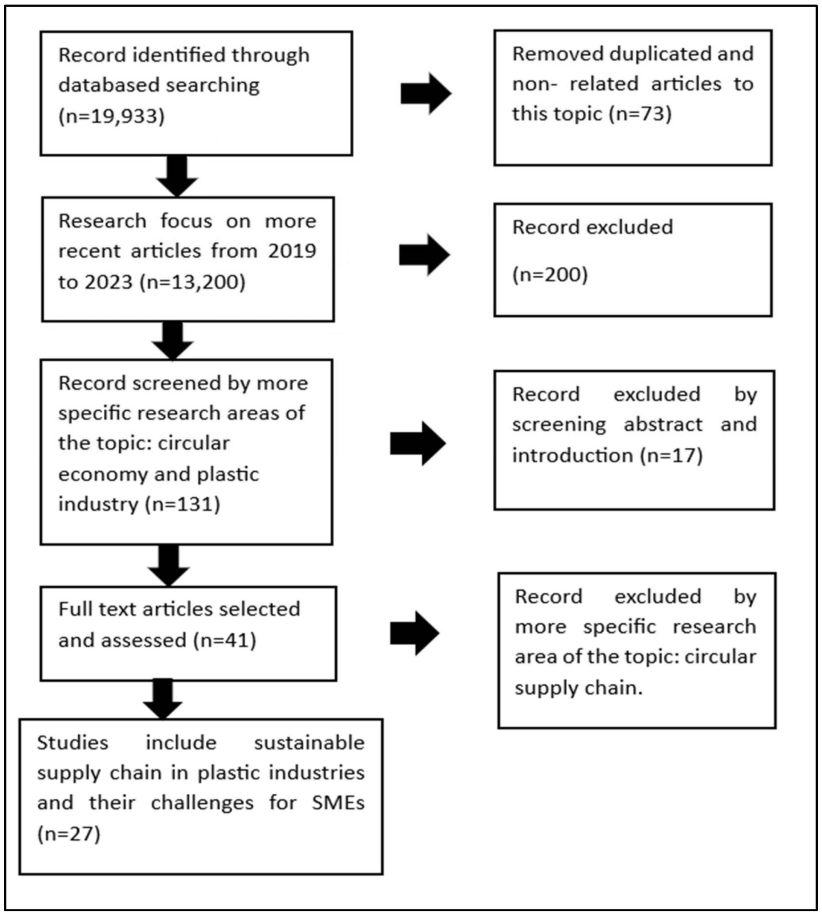

Figure 1. PRISMA methodology.

3. Research Findings

For many years, plastics have been an essential part of contemporary life due to their affordability, resilience, and adaptability, but the sector is now facing increasing pressure to address environmental concerns and embrace sustainability. In this sector, being green is not only a question of corporate social responsibility; it is also a critical business decision that will ensure long-term viability and profitability. The refusal to adapt exposes businesses to a risk of loss to their reputation, as well as possible legal and financial repercussions when consumers and authorities demand more responsible behavior. Embracing sustainability may result in decreased expenses, increased value of the brand, entry into new markets, and conformity with the expanding eco-aware consumer base [12].

3.1. Circular Economy

A key tactic for reducing the adverse environmental effects of plastic manufacturing is the shift from a linear to a circular economy. It aims to minimize waste by promoting the reuse, recycling, and repurposing of materials throughout their life cycle. This can be accomplished through a variety of tactics, including value-recovery techniques, improved product and capital asset utilization, waste reduction, and product life extension [13]. By promoting a more ethical and resilient supply chain, this strategy improves the company's ecological footprint.

A leading innovator in the plastic-manufacturing industry champions closed-loop recycling systems. This company collaborates with another organization to incentivize businesses and eco-conscious individuals to participate in the collection and recycling of their products. Collected materials are repurposed to create new goods, furthering the sustainability cycle. Notably, this collaboration involves the first fully recyclable water filter in the United States. The rewards earned through recycling contribute to charities,

communities, and educational institutions. Additionally, the collaborating organization's program addressing water-related issues in indigenous communities exemplifies a holistic approach to social, economic, and environmental sustainability [14].

3.2. Clean Manufacturing Techniques for Plastic

Clean manufacturing techniques focus on minimizing the environmental impact of production processes. This involves reductions in energy consumption, emissions, and waste generation throughout the manufacturing cycle.

A leading chemical company is collaborating with a nuclear energy company to develop a sustainable manufacturing project. This project aims to significantly reduce carbon emissions, fostering a circular economy and enhancing operational reliability. By doing so, the company is positioning itself at the forefront of the global energy transition, adhering to strict regulations, and improving supply chain sustainability and transparency. This effort serves as a model for integrating renewable energy into production, benefiting both local and global communities while driving the company's growth [15].

3.3. Extended Producer Responsibility (EPR)

In the plastics business, extended producer responsibility (EPR) has become a viable policy tool for supporting sustainable supply chain management. EPR transfers to the product's manufacturer the material and financial cost of managing an end-of-life product, according to the OECD (2001). Producers are encouraged by this strategy to use sustainable production methods, invest in recycling infrastructure, and design products for recyclability. Research has indicated that EPR is a useful tool for increasing recycling rates and decreasing the production of plastic waste [15]. For example, a WRI (2020) study discovered that the use of EPR significantly increased Mexico's recycling rates for plastic packaging.

3.4. Progress Monitoring: Tracing and Tracking

To ensure accountability and continuous improvement, progress monitoring is essential for sustainability projects. Regular evaluation and feedback are crucial for monitoring the success of these initiatives and making informed decisions. For instance, Queen of Raw's Materia Mx subscription underscores the critical role of tracing and tracking in sustainable supply chains, having helped over 150,000 companies save one billion gallons of water and divert 500 tons of textiles from landfills since its 2014 launch [16].

3.5. SME-Friendly Policies

To support SMEs in the plastics industry, policies should include establishing recycling cluster zones for efficient waste processing and smart regulations that promote sustainable practices while penalizing unsustainable ones. Investment in advanced recycling infrastructure can enhance SMEs' capabilities in eco-friendly recycling and circular economy contributions. The Horizon Europe initiative supports such endeavors by funding projects that improve waste management and create new recycled material value chains, similar to the UK's Plastic Packaging Tax, which encourages the use of recycled plastic by imposing a fee on less sustainable packaging [17].

4. Methodology

Our approach comprised a thorough examination of multiple choices to attain sustainability across the plastics sector. We addressed the uncertainties inherent in sustainability evaluations by employing advanced techniques, like the fuzzy ELECTRE and AHP (FAHP) framework given in Figure 2. By giving decision makers in the plastics industry a solid framework and comprehensible, practical information, we hope to support their efforts in steering the sector toward a sustainable future [18,19]. Although there are various methods available to undertake decision analysis, the reason behind using Fuzzy ELECTRE and AHP was its variable and robust approach. This method is ideal for research purposes because it has the capability to handle various criteria by handling different types of data,

which can be both quantitative and qualitative. This was the reason for taking this method, as it can help with complex decision making and give practical decisions. The selection of the criteria and alternatives was carried out by conducting a literature review and from professionals that had experience in working with plastics industries [15,17,20–23]. Expert assistance was also important for constructing the decision matrices used in the MCDA approach.

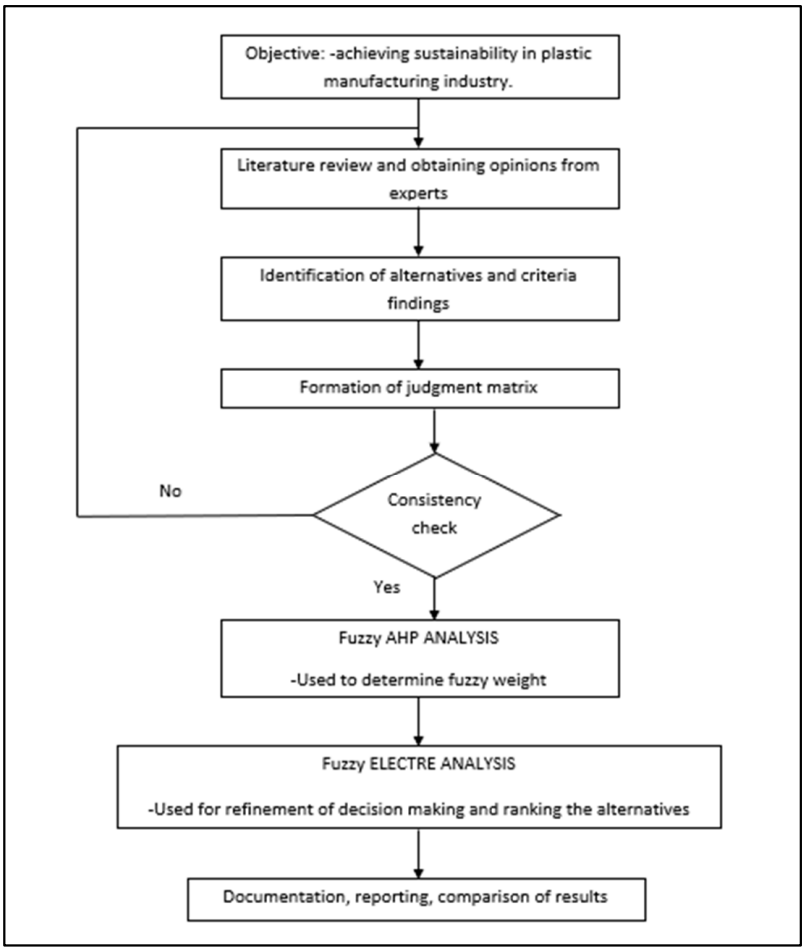

Figure 2. Fuzzy ELECTRE and AHP MCDA technique framework.

5. Discussion

SMEs seeking a competitive edge and a successful transition to circular practices can leverage a four-pronged strategy. First, they must engage in strategic planning, utilizing a PESTEL analysis to identify key resources and understand product life cycles. Process standardization, achieved through international certifications and quality management systems, then ensures operational flexibility and adaptability. Next, efficiency takes center stage, driven by continuous process innovation and a sharp focus on key performance indicators. Finally, investing in a skilled workforce, particularly in R&D, empowers adaptation to change and regulatory compliance, while strong R&D leadership champions transformation. This holistic approach equips SMEs with the tools and knowledge needed to thrive in a circular economy. Figure 3 shows the various parts in which the SMEs must work.

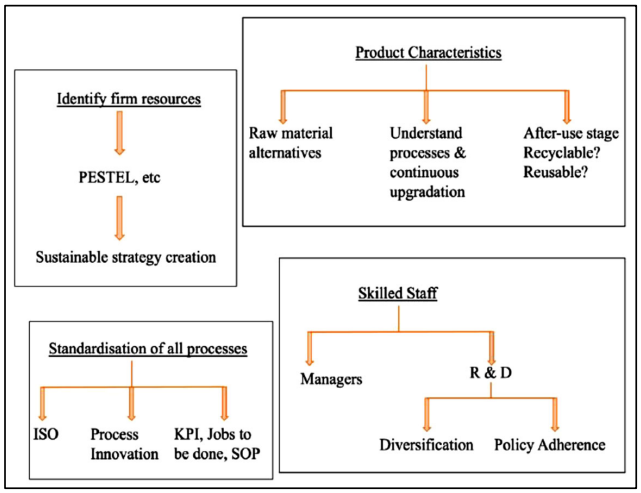

Figure 3. Areas to work on to attend sustainability.

5.1. MCDA Implications

Using the information gathered from the literature and the professional opinions for the defined issue statement, we were able to determine the appropriate approach to achieve sustainability in the plastic sector after following the technique in accordance with the fuzzy ELECTRE flowchart. Comparisons revealed that out of all the options, option A8 (progress monitoring) was the most favored. Alternatives A6 (SME-friendly policies) and A7 (phasewise EPR guidelines) came after this, where the graphic shows the outranking relationships between the various choices. The outranking graph provides important information, one of which is that alternate A4 (incentives for upcoming projects) did not rank higher than any of the other alternatives. In contrast to option A5, which was the public–private partnership, it was not superior to any other option. Out of the eight options, option A5 (public–private partnership) was found to be the least effective. Refer to Figure 4 for the outranking and interdependence. International regulations play a major role and impact greatly on the SME operational environment. International regulations related to circular economy and EPR vary from country to country, due to which they face lot of challenges in adhering to those complexities in all regions. The financial burden on SMEs is more due to compliance cost, as well as they have to follow rules, products standards, manufacturing techniques, environmental rules, and various things according to different regions.

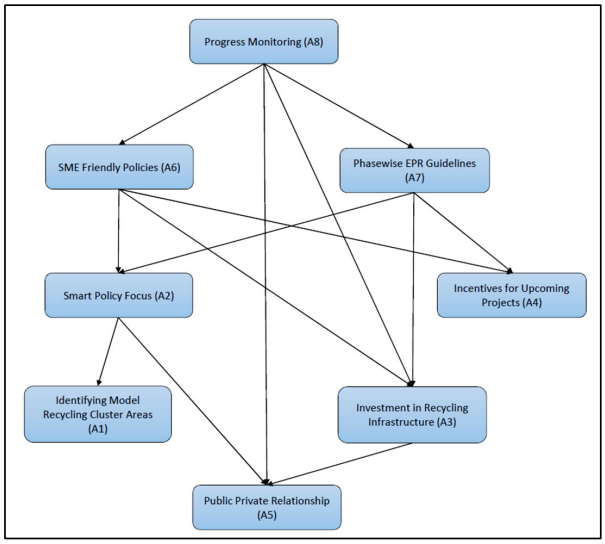

Figure 4. Outranking graph.

Every country is trying to move toward more sustainability, due to which the international regulations on plastic is increasing day by day, so it is difficult for SMEs to keep up with countries as they tend toward more technological innovations. Therefore, SMEs need proper guidance and support from governments, international organizations, and industries to navigate through this complexity and web of international regulations.

5.2. Future Research Direction

Since progress monitoring is a critical factor from this study, future studies should look into combining MCDA methods with advanced decision-making tools, like machine learning, which allows for real-time market and environmental adaptability. This will enhance the scalability and resilience of integrating blockchain, IoT, and machine learning in the plastic manufacturing supply chain.

6. Conclusions

Obstacles hinder small- and medium-sized plastic manufacturers (SMEs), as they strive for sustainable practices and supply chains. Policy ambiguity, lack of vision, and financial constraints are key hurdles. Encouraging tangible benefits is crucial to drive transformative investments. Tackling these issues requires a three-pronged approach: enhanced skills through programs like the Skill Development Program, transparent policies implemented collaboratively by SMEs and government agencies, and financial support. Additionally, a circular economy mindset fosters agility and competitiveness. Industry–academia partnerships are vital for R&D, innovation, and global progress.

Phased EPR guidelines and progress monitoring are essential for sustainability. This review stresses long-term planning, emphasizing waste management as a way to reduce recycling costs and generate revenue. Progress monitoring and traceability of the supply chain are key factors for embracing a circular economy as a strategic move for future sustainability and reduced challenges.

Author Contributions: Conceptualization, N.P., P.T., H.T., M.A.P. and Y.B.; methodology, N.P., P.T., H.T., M.A.P. and Y.B.; validation N.P., P.T., H.T., M.A.P. and Y.B.; formal analysis, H.T. and M.A.P.; investigation, N.P., P.T., H.T., M.A.P. and Y.B.; resources, N.P., P.T., H.T., M.A.P. and Y.B.; data curation, N.P., P.T., H.T., M.A.P. and Y.B.; writing—original draft preparation, N.P., P.T., H.T., M.A.P. and Y.B.; writing—review and editing, S.A.K.; visualization, N.P., P.T., H.T., M.A.P. and Y.B.; supervision, S.A.K.; project administration, S.A.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data will be available upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Carroll, A.B. A Three-Dimensional Conceptual Model of Corporate Performance. *Acad. Manag. Rev.* **1979**, *4*, 497–505. [CrossRef]
2. Geyer, R.; Jambeck, J.R.; Law, K.L. Production, Use, and Fate of All Plastics Ever Made. *Sci. Adv.* **2017**, *3*, e1700782. [CrossRef] [PubMed]
3. Martínez-Soria, V.; Gabaldón, C.; Penya-Roja, J.M.; Palau, J.; Álvarez-Hornos, F.J.; Sempere, F.; Soriano, C. Performance of a Pilot-Scale Biotrickling Filter in Controlling the Volatile Organic Compound Emissions in a Furniture Manufacturing Facility. *J. Air Waste Manag. Assoc.* **2009**, *59*, 998–1006. [CrossRef] [PubMed]
4. Unilever's Global Strategy for Reducing Supply Chain Plastic | Sustainability Magazine. Available online: https://sustainabilitymag.com/sustainability/unilevers-global-strategy-for-reducing-supply-chain-plastic (accessed on 9 May 2024).
5. U.S. National Recycling Goal | US EPA. Available online: https://www.epa.gov/circulareconomy/us-national-recycling-goal (accessed on 9 May 2024).
6. Sustainability Decarbonization and Industry Initiatives—Survey Findings and Analysis. Available online: https://www.aspentech.com/en/resources/report/sustainability-decarbonization-and-industry-initiatives-survey-findings-and-analysis (accessed on 11 February 2024).

7. Ansari, Z.N.; Qureshi, M.N. Sustainability in Supply Chain Management: An Overview. *IUP J. Supply Chain Manag.* **2015**, *12*, 24–46.
8. Seuring, S.; Mü Ller, M. From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management. *J. Clean. Prod.* **2008**, *16*, 1699–1710. [CrossRef]
9. Carter, C.R.; Rogers, D.S. A Framework of Sustainable Supply Chain Management: Moving toward New Theory. *Int. J. Phys. Distrib. Logist. Manag.* **2008**, *38*, 360–387. [CrossRef]
10. Page, M.J.; Moher, D.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. PRISMA 2020 Explanation and Elaboration: Updated Guidance and Exemplars for Reporting Systematic Reviews. *BMJ* **2021**, *372*, n160. [CrossRef] [PubMed]
11. Das, S.; Barve, A.; Sahu, N.C.; Muduli, K. Enabling Artificial Intelligence for Sustainable Food Grain Supply Chains: An Agri 5.0 and Circular Economy Perspective. *Oper. Manag. Res.* **2023**, *16*, 2104–2124. [CrossRef]
12. Chardine-Baumann, E.; Botta-Genoulaz, V. A Framework for Sustainable Performance Assessment of Supply Chain Management Practices. *Comput. Ind. Eng.* **2014**, *76*, 138–147. [CrossRef]
13. Fiksel, J.; Sanjay, P.; Raman, K. Steps toward a Resilient Circular Economy in India. *Clean Technol. Environ. Policy* **1982**, *23*, 203–218. [CrossRef] [PubMed]
14. Case Study: TerraCycle—Recycling the 'Unrecyclable'. Available online: https://wedocs.unep.org/20.500.11822/40503 (accessed on 9 May 2024).
15. Integrate Extended Producer Responsibility Within the International Plastics Treaty. Available online: https://apps1.unep.org/resolutions/uploads/integrate_epr_within_the_international_treaty_on_plastics_pollution_1.pdf (accessed on 9 May 2024).
16. Why Queen of Raw Is One of the Most Innovative Companies of 2024. Available online: https://www.fastcompany.com/91039799/queen-of-raw-most-innovative-companies-2024 (accessed on 9 May 2024).
17. Increasing the Circularity in Plastics Value Chains | Horizon-Europe.Gouv.Fr. Available online: https://www.horizon-europe.gouv.fr/increasing-circularity-plastics-value-chains-33592 (accessed on 9 May 2024).
18. Daneshvar Rouyendegh, B.; Erol, S. Selecting the Best Project Using the Fuzzy ELECTRE Method. *Math. Probl. Eng.* **2012**, *2012*, 790142. [CrossRef]
19. Kabir, G.; Hasin, A.; Ahsan, M. Comparative Analysis of TOPSIS and Fuzzy TOPSIS for the Evaluation of Travel Website Service Quality. *Int. J. Qual. Res.* **2012**, *6*, 169–185.
20. Abraham, B. EPR for Plastic Packaging Waste Is a Step in the Right Direction But Has Set Impossible Targets. *India Times*, 2022. Available online: https://www.indiatimes.com/news/india/epr-guidelines-for-plastic-packaging-recycling-562665.html.
21. Chidepatil, A.; Bindra, P.; Kulkarni, D.; Qazi, M.; Kshirsagar, M.; Sankaran, K. From Trash to Cash: How Blockchain and Multi-Sensor-Driven Artificial Intelligence can Transform Circular Economy of Plastic Waste? *Adm. Sci.* **2020**, *10*, 23. [CrossRef]
22. MacArthur, D.E.; Waughray, D.; Stuchtey, M.R. The new plastic economy, rethinking the future of plastics. In *World Economic Forum*; Ellen MacArthur Foundation and McKinsey & Company: London, UK, 2016.
23. Moktadir, A.; Rahman, T.; Jabbour, C.J.C.; Mithun Ali, S.; Kabir, G. Prioritization of drivers of corporate social responsibility in the footwear industry in an emerging economy: A Fuzzy AHP Approach. *J. Clean. Prod.* **2018**, *201*, 369–381. [CrossRef]