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Sustainable Supply Chain Management: Balancing Environmental and Economic Factors in Engineering-Driven Industries

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In today's globalized economy, sustainable supply chain management (SSCM) has become a paramount concern for engineering-driven industries. This research explores the intricate balance between environmental and economic factors in the pursuit of sustainability within supply chain operations. Engineering-driven industries, characterized by complex manufacturing processes and intricate logistical networks, are particularly challenged to integrate environmental and economic considerations seamlessly. This paper seeks to bridge this gap.We delve into the critical aspects of SSCM, including the identification of eco-efficient technologies, green supplier selection, and demand forecasting. We propose a holistic framework that incorporates sustainability criteria at every stage of the supply chain, from procurement to distribution. The goal is to minimize environmental impact without compromising economic performance. This research contributes to the body of knowledge in SSCM by providing a comprehensive framework tailored to engineering-driven industries. By striking a harmonious balance between environmental and economic factors, organizations can enhance their competitiveness, reduce their carbon footprint, and contribute to a more sustainable future.
Keywords: Sustainable Supply Chain Management, Engineering-Driven Industries, Environmental Factors, Economic Factors, Eco-efficiency, Sustainability Criteria, Regulatory Compliance.

1. Introduction

Sustainability has emerged as a central theme in contemporary industrial discourse, permeating all facets of business operations. In engineering-driven industries, where the nexus of technology, innovation, and production fuels global economic growth, the question of how to effectively balance environmental concerns with economic imperatives is of paramount importance. The complex nature of these industries, with intricate supply chains and resource-intensive processes, presents unique challenges and opportunities in the pursuit of sustainability. This paper explores the critical domain of Sustainable Supply Chain Management (SSCM) in engineering-driven industries, emphasizing the imperative to balance environmental and economic factors.

Engineering-driven industries, encompassing sectors such as automotive, aerospace, electronics, and heavy machinery, are pivotal players in the global economic landscape. They form the backbone of technological advancement and infrastructure development. Yet, these industries are also notable contributors to environmental degradation and resource consumption. Recognizing this paradox, there is growing

consensus that engineering-driven industries must not only innovate but also transform their supply chains to mitigate environmental harm.
Engineering-driven industries have significant global environmental footprints due to their scale and resource utilization. Addressing their sustainability is crucial in the larger context of mitigating climate change and reducing ecological harm. Governments worldwide are implementing stringent environmental regulations, imposing costs and penalties on non-compliance. An effective SSCM strategy is essential to navigate this regulatory landscape as shown in figure 1.

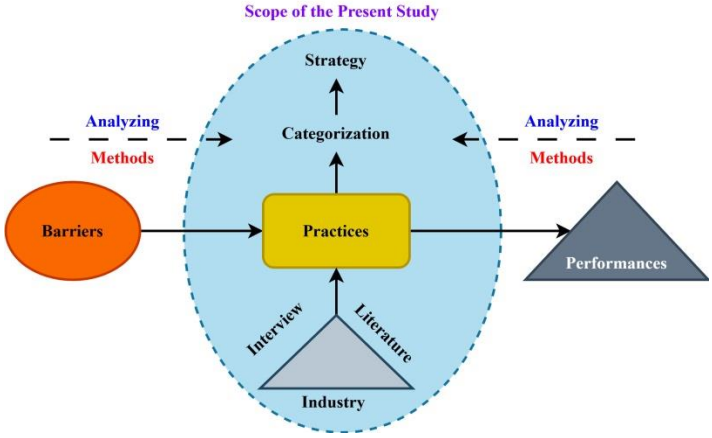

Figure 1: The structure of studying SSCs considering practices.

Today's consumers are increasingly environmentally conscious and seek products and services with green credentials. A sustainable supply chain is a selling point that can differentiate engineering-driven industries in the market. Balancing environmental and economic factors can lead to cost savings and operational efficiencies. A sustainable supply chain is not just a moral choice; it's also a business imperative. Sustainable practices can safeguard the long-term viability of engineering-driven industries. By reducing waste, conserving resources, and minimizing environmental risks, these industries can ensure their continued existence.

Balancing Environmental and Economic Factors
Balancing environmental and economic factors in engineering-driven industries is a multifaceted challenge that extends across the entire supply chain. It involves a delicate equilibrium, where environmental considerations do not jeopardize economic viability, and vice versa. To achieve this balance, organizations are implementing a range of strategies, including: Adopting innovative, energy-efficient, and environmentally friendly technologies to minimize the environmental footprint while optimizing production processes.

Partnering with suppliers who share a commitment to sustainability, ensuring that raw materials and components are sourced responsibly. Utilizing advanced forecasting techniques to streamline inventory management, reduce waste, and lower energy consumption. Staying abreast of environmental regulations and proactively implementing measures to ensure compliance, avoiding costly fines and reputational damage. Adhering to industry-specific sustainability standards and certifications, which convey a commitment to environmentally responsible practices.

In this paper, we will delve into these strategies in greater detail, presenting a comprehensive framework for implementing sustainable supply chain management in engineering-driven industries. Real-world case studies from various sub-sectors will illustrate the practical application of these strategies and the tangible benefits they yield.

2. Literature Review

This foundational paper offers a systematic literature review and presents a comprehensive framework for achieving sustainability in supply chain operations. The authors argue that achieving sustainability requires a holistic approach that integrates economic, environmental, and social dimensions. They categorize the literature into different themes, including green supply chain, green practices, and performance indicators, providing a structured overview of the field. This paper establishes the groundwork for understanding sustainability in supply chain management.

Tukker and Jansen introduce the concept of the "Sustainability Wheel" as a practical tool for achieving balance between economic and environmental performance within supply chains. The Sustainability Wheel offers a visual representation of trade-offs and synergies between various sustainability dimensions. This tool aids in decision-making and strategic planning, providing a valuable resource for practitioners and researchers in the field of Sustainable Supply Chain Management.

This research hones in on the Indian automotive industry, examining how green supply chain management practices enhance environmental sustainability. It delves into the specific challenges and opportunities in this sector and highlights the strategies and practices that have been implemented successfully. The study underscores the importance of contextualizing sustainable supply chain practices based on regional and sector-specific characteristics.

Rahman and Subramanian offer a comprehensive review of performance measurement in the context of global supply chains. They analyze the literature and propose a framework for measuring the performance of sustainable supply chains, emphasizing the need for integrating both environmental and economic dimensions. This framework provides a structured approach for assessing the impact of sustainability initiatives on supply chain performance.

Leal and Cortimiglia present an extensive review of the literature on sustainability in the supply chain. They examine various aspects of sustainability, including environmental and social dimensions, and discuss the challenges and opportunities faced by organizations. This review paper helps build a comprehensive understanding of the multi-faceted nature of sustainability in supply chains.

Elhedhli and Merrick focus on the modeling and computational aspects of SSCM. They review models, algorithms, and challenges related to sustainable supply chain management, offering insights into quantitative approaches for achieving sustainability in supply chains. This paper is vital for those interested in the analytical and mathematical aspects of SSCM.

Bień and Czech conduct a qualitative study, providing insight into how large and medium-sized manufacturers integrate environmental sustainability into their supply chain management practices. The study explores the motivations, challenges, and benefits associated with environmental sustainability efforts, offering practical examples of how companies are striving to balance economic and environmental factors.

This paper, situated in the automotive industry, delves into environmental performance measurement. It explores various techniques used to assess environmental performance, providing valuable insights into how organizations in this sector are addressing sustainability concerns. The findings contribute to a deeper understanding of how balancing environmental and economic factors is being approached in a specific engineering-driven industry.

3. Proposed System

Ethical Implications of AI in Marketing - A Real-Time Case Study

This section presents a case study of Sedex to demonstrate the implementation and effectiveness of solutions for responsible and sustainable supply chain management (SCM). The case study highlights the utilization of innovation, a multi-stakeholder approach, and effective governance and supra-agency in achieving responsible and sustainable SCM. Established in 2004, Sedex (The Supplier Ethical Data Exchange) is a non-profit membership organization that collaborates with buyers and suppliers on a global scale to facilitate advancements in responsible and ethical business practices throughout global supply chains (Sedex Global (a)). Sedex is a globally recognized collaborative platform that offers advanced services for the management and dissemination of ethical supply chain data. This platform is extensively utilized by multinational corporations to get insights into, monitor, and effectively mitigate risks associated with their supply chains, while also striving to enhance industry standards (Sedex (a)). Sedex is an organization that facilitates collaboration among a vast network of over 38,000 organizations, encompassing buyers, suppliers, and audit firms. These companies operate throughout 28 diverse sectors, such as chemicals, engineering, IT, telecom & electrical, pharmaceuticals, and pharmaceutical products. Sedex's reach extends to over 150 countries worldwide. (Sedex (b))

Innovation:

Sedex provides a digitally protected database that enables its members to save, exchange, and analyze data pertaining to four primary domains: labor standards, occupational health and safety, environmental practices, and corporate ethics (Sedex (a)). Sedex offers three distinct categories of membership, each representing varying levels of functionality inside the Sedex system. These categories include Buyer membership, Buyer/Supplier membership, and Supplier membership (Sedex (c)). The electronic system of

Sedex is responsible for the collection and analysis of data pertaining to ethical and responsible business practices within supply chains (Sedex (d)).
Furthermore, Sedex provides a range of reporting tools that allow buyers to monitor the performance of their suppliers. Additionally, Sedex offers an enhanced Risk Assessment Tool (Sedex (d)) to further enhance its capabilities.
Suppliers that engage in the Sedex network have the capability to efficiently and economically exchange information with numerous consumers (Sedex (d)). Sedex facilitates the reduction of multiple audits by permitting the sharing of data among numerous customers. Consequently, the implementation of the Sedex online system has the potential to enhance the traceability, transparency, and flexibility of supply chains, while also improving stakeholder engagement and communication. In relation to the primary ethical hazards within the supply chain, Sedex acknowledges that the principal risks exhibit a considerable range of diversity. Frequent instances of noncompliance in social audits encompass health and safety concerns, with disobedience pertaining to salaries and working conditions. Challenges may arise in addressing additional concerns like as discrimination, bullying, and bonded labor, as these issues may not always be readily identifiable through the audit procedure. According to a briefing provided by Sedex, it has been observed that fire safety non-compliances constitute approximately one-third of all health and safety non-compliances on a global scale (Sedex (g)). The utilization of data mining at this level facilitates companies in comprehending global trends and the magnitude of challenges. Sedex aims to alleviate the challenges encountered by suppliers who are confronted with the need to undergo several audits, questionnaires, and certificates. However, it also serves as a catalyst for enhancing the ethical performance of supply chains on a worldwide scale (Sedex (a)). During the period when the case study was done, Sedex was engaged in efforts to enhance the capabilities of its technology team in order to bolster the assistance provided for the quality and timeliness of its deliveries. Furthermore, Sedex has undertaken research on the development of an online extranet platform with the aim of facilitating enhanced collaboration and more streamlined talks among its members (Sedex, 2017).

Muti-Stakeholder Approach
The primary objective of Sedex is to foster cooperation, enhance visibility, and develop the necessary capabilities to elevate standards throughout all levels of the supply chain (Rangi et al., 2015). The Sedex Stakeholder Forum (SSF), formerly referred to as the Associate Auditor Groups (AAG), convenes prominent figures from the ethical trade and responsible sourcing sector to engage in collective discussions and find solutions to the obstacles they encounter (Sedex, 2017). The primary objective of the Sedex Sustainability Standards Framework (SSF) is to promote the convergence of auditing practices and the adoption of best practices within the field of auditing (Sedex, 2017). The Forum is comprised of several stakeholders, including brands, retailers, suppliers, NGOs, industry experts, associations, and monitoring firms. These stakeholders play a vital role in the practice of ethical trade auditing, as highlighted in the Sedex report of 2017. The SSF is comprised of a series of active working groups (Sedex 2017). The working groups within the SSF collaborate in order to provide responsible sourcing content and procedures that are suitable for their intended use (Sedex, 2017). The solutions provided are intended to benefit a wide range of users and stakeholders, including Sedex members, non-members, workers, and their respective communities. The primary objective of these solutions is to enhance business performance and promote the well-being of workers. (Sedex, 2017). Additionally, the SSF offers advice and direction to the employees of Sedex. They contribute to the development of goods and services aimed at effectively managing responsible sourcing within supply chains (Sedex, 2017). Sedex aims to involve a broader international audience in the development and evaluation of responsible sourcing solutions through the implementation of the Supplier Self-Assessment Questionnaire (SSF) (Sedex, 2017).
The SSF aims to cultivate an image of inclusivity, global reach, and interactivity.

Effective Governance and Supra-Agency
Sedex is not a standard-setting body, lacking a code of conduct and accreditation. Sedex aims to help firms share and manage supply chain information for continuous improvement (Sedex (a)). Sedex recommends implementing Ethical Trading Initiative (ETI) provisions in labor, health, and safety, environmental, and business ethics (Sedex (g)). Sedex is code neutral, therefore potential members do not need to meet specific criteria to join. Sedex membership demonstrates commitment to supply chain improvement at an organization. Sedex provides solutions to help firms assess and decide on their next steps. The assessment includes six steps for improved traceability, transparency, adaptability, legal compliance, and stakeholder management:

1. Supply chain mapping - Sedex enables firms to identify and map their suppliers across different layers.
2. Sedex online members only Using the Self-Assessment Questionnaire (SAQ), Sedex asks members about international labor standards, health and safety, the environment, and business ethics.
Members offer feedback on risk and maturity indicators for handling social, governance, and environmental challenges. Sedex is a multi-sector organization with one SAQ. The questionnaire filters questions based on the supplier profile. During the case study, Sedex was developing a new modular functionality to enhance client or sector specifications. Risk Assessment tool developed by Sedex in collaboration with Maplecroft, worldwide risk experts. The instrument evaluates various elements, such as human rights violations, political risk, corruption, and child labor, as well as site management proficiency and risk mitigation (Sedex (e)). Effective risk assessment is crucial for large firms with complicated supply chains, as it helps them prioritize their efforts.
4. Assessment – The Sedex Stakeholder Forum created the Sedex Members Ethical Trade Audit (SMETA) to meet member demand for a more accessible ethical audit report format (Sedex (f)). Sedex (f) states that SMETA intends to decrease ethical trade auditing duplication, benefiting retailers, consumer brands, and suppliers. Sedex clarifies that SMETA is not a code of conduct, methodology, or certification process (Sedex (f)). The audit procedure represents ethical audit approaches based on best practices (Sedex (f)). Approximately 10,000 audits are uploaded annually to Sedex. Initially, 90% of audits on Sedex were based on company codes, but today 90% are based on SMETA, proving its success. SMETA is a widely utilized audit approach worldwide. Sedex attributes its success on involving audit businesses, brands, retailers, and suppliers in its development. SMETA comprises three components: (1) Standardized corrective action plan format; (2) Best practices for ethical trade audits; (3) Common audit report format (Sedex (i)).
5. Reporting Sedex suggests that increasing supply chain awareness can reduce risk and safeguard a company's reputation. Sedex provides detailed data to improve supply chain visibility, identify patterns, notify possible concerns, and prioritize resources. With its vast data, Sedex can address risks and provide inspiration for change through good practices.
6. Capacity building - Sedex provides tools like the Supplier Workbook for capacity building. The free, public workbook provides practical direction for global suppliers to understand ‘good practice’ for Ethical Trading Initiative (ETI) and Code criteria. The Workbook also advises providers on meeting these standards.
Sedex wants to increase capacity at the expanded supply chain's base.
The SMETA approach enables auditors to report non-compliance with both the ETI base code (a measured version of ILO standards) and local regulations. The first step is to identify conflicts between local laws and international frameworks. The next phase entails collaborating with a provider to meet legal requirements. If a supplier already meets this quality, it may be difficult to get them to strive for a greater level. Companies can take numerous ways. Firstly, it is the purchasing power tied to client needs. The second step is to show the business benefit to the supplier concerned. Cooperation and collaboration can lead to significant change. Companies like Sedex collaborate on a common framework. A group of companies seeking the same information can dramatically impact the behavior of an individual company. However, Sedex emphasizes the necessity for standardization in international settings. Conflicting laws and norms in different nations can complicate the supply chain and confuse providers. This fragmentation also hinders firms and other actors from adhering to several standards.
Many corporations and organizations believe voluntary norms are effective tools for corporate responsibility, according to Sedex's assessment of the current legislative framework. Some larger corporations want legislation to level the playing field. According to Sedex, there are innovative techniques to analyze how legislation works. For example, the UK modern slavery bill has sparked significant debate among the legal profession. This discussion compares the effectiveness of a disclosure-based norm to expanding current legislation to compel reporting on human rights in the supply chain. The respondent emphasized the potential effectiveness of voluntary norms. While legislation can level the playing field, it is important to consider the administrative cost on supply chains, especially SMEs. Enforcing laws is vital.
Legislation addresses many supply chain hazards, but it is not enforced.
A balance between suitable legislation and effective enforcement is crucial. A cross-sector approach to responsible and sustainable supply chain management, as emphasized by Sedex, requires collaboration. Instead than reinventing the wheel, consider existing legislation, initiatives, mechanisms, and standards. Successful implementation is essential for supply chain policies to succeed.

4. Conclusion

A study on responsible and sustainable supply chain management (SCM) explores ethical decision-making and provides a theoretical framework for future research. To find sustainable and ethical supply chain management solutions, this study combines current knowledge with recent theoretical and empirical advances. The theoretical account has two components. This concept of responsible SCM is based on the concepts of 'responsible supply chain management' and 'sustainable supply chain management'. Second, responsible and sustainable supply chain management involves considering all three dimensions of sustainability (economic, environmental, and social), collaborating with partners, building long-term relationships, and meeting legitimate stakeholder needs, such as customers, NGOs, suppliers, and legal authorities. A theoretical explanation and stakeholder dialogue identified three solutions for responsible and sustainable SCM difficulties faced by enterprises. To improve accountability and sustainability, supply chain stakeholders should use new organizational and technology solutions that improve monitoring, assessment, efficiency, and communication between levels. The report highlights two technologies that could transform SCM: big data analysis and blockchain technology. Second, stakeholders should collaborate on supply chains based on trust and learning. Thirdly, this study proposes new SCM governance and commercial models. Models should emphasize shared accountability and collaboration among supply chain stakeholders, utilizing emerging technologies. Hence, this study proposes a novel method to responsible and sustainable SCM by integrating technological, political, and ethical solutions (innovation, multi-stakeholder approach, supra-agent responsibility and governance). This article emphasizes the importance of studying the interwoven economic, sociological, environmental, ethical, and human rights aspects of SCM. The Sedex case study presents non-state actor governance methods that effectively manage SCM concerns and ensure responsibility and sustainability. Sedex improves supply chain sustainability by implementing three solutions from this study. Sedex invests in technology to share and analyze supply chain data, collaborates with stakeholders to build features, and promotes positive behavior change among members.

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