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Sustainable Business Models for Enhancing Green Supply Chain Performance

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ABSTRACT

The increasing challenge on environmental issues has necessitated the emergence of sustainable business models (SBMs) as a way of improving green supply chain performance. This study examines how SBM design affects the outcome of green supply chain, focusing on how superior technologies, environmental impact mitigation policies, and resilience aspects affect the outcome. The literature review is a thorough description of how the latest scholarly articles, industry reports, and case studies reveal the complete picture of how SBMs contribute to greater operational efficiency, environmental sustainability, and supply chain resilience. Some of the key findings include the need to incorporate the principles of circular economy, use technologies, e.g., blockchain and IoT to achieve transparency and traceability, and implement such proactive environmental approaches as green sourcing and waste reduction. It also highlights the importance of stakeholder cooperation, agile, and risk management in the development of resilient green supply chains in the research. In addition, the paper provides a conceptual model of developing and measuring sustainability performance indicators with the focus of a multi-dimensional perspective on environmental, economic, and social indicators. The study ends with an explanation of the managerial implications of using SBMs, the societal impacts of green supply chain, and the future research directions in the event of global disruptions and technology changes. Overall, the research can expand the literature base on sustainable supply chain management and provide useful information to practitioners interested in making their activities more sustainable and resilient

Keywords: Sustainable Business Models, Green Supply Chains, Environmental Performance, Supply Chain Management, Resource Optimization, Circular Economy, Corporate Sustainability

1. INTRODUCTION:

The increasing importance of climate change and depletion of resources has led to the need of businesses to pursue sustainable business practices throughout their operations. Specifically, the adoption of sustainable business models (SBMs) in green supply chains is a crucial chance to not only reduce environmental effects but also to improve performance and sustainability of operations and profitability in the long run. The study explores the potential of innovative SBMs to propel the performance of green supply chains towards more sustainable and resilient global economy.

Several theoretical frameworks have greatly contributed in the study of Sustainable Business Models in the Enhancement of Green Supply Chain Performance. Resource-Based View (RBV) was concerned with capability of firms to leverage on unique resources and capabilities to create a competitive advantage by integrating sustainability in the supply chain activities (Barney, 1991). The Stakeholder Theory was also instrumental in the conception of the capability of companies to harmonize the demands of the various stakeholders including customers, suppliers and regulatory agencies to develop sustainable business models that facilitate the adoption of green supply chains practices (Freeman, 1984). The structure of the Triple Bottom Line (TBL) which underlined the need to pursue economic, environmental and social goals also acted as a platform to evaluate the impact of sustainable business models on the overall performance of the supply chain (Elkington, 1997). The Institutional Theory explained how the external pressure that comprised the regulatory requirements and expectations of the society affected the incorporation of sustainable practices in the supply chain of the firms (DiMaggio & Powell, 1983). The Circular Economy (CE) model was the last one to introduce the resource efficiency and waste reduction into the sustainable business strategies and provide companies with an opportunity to enhance their sustainability and supply chain performance (Kirchherr et al., 2017). All these theories contributed to the information as to how the sustainable business models would help in increasing the efficiency of the green supply chain by addressing the environmental concerns without affecting the profitability of the business.

Companies were moving towards the circular supply chain where they focused on the reuse and recyclability of products and their durability. Such transition contributed to waste reduction and resources conservation, which is in compliance with sustainability requirements, but it may also lead to cost saving in the long run (Supply Chain Tech News, 2025). Blockchain-based transparency, freight optimization with the help of AI, real-time tracking with the help of IoT, and digital analytics became all the more essential to the green supply chain, allowing to trace it better, improve efficiency of the operations and monitor the environmental effect (Green Logistics in 2025, 2025;

Supply Chain Tech News, 2025). Increasing consumer consciousness and the desire to see an environmentally responsible product forced companies to implement the traceability technology such as blockchain to guarantee the transparency of their supply chains and comply with regulations (Supply Chain Tech News, 2025). The importance of decarbonization as a regulatory and competitive necessity was reflected in many companies that were determined to reach net-zero carbon emissions by reshaping logistics, going electric and streamlining routes (Green Logistics in 2025, 2025; Supply Chain Tech News, 2025). The emergence of omnichannel retailing required new green supply chain designs to strike a balance between carbon emissions and profitability and computational modeling was used to optimize these non-trivial systems to meet both economic and environmental goals (Integrating Sustainability in Green Supply Chains, 2025). Although sustainability has increasingly become an important issue, most companies found it difficult to measure and manage sustainability metrics because of disjointed data and cumbersome processes, and few of them had effective mechanisms to deal with sustainability (World Economic Forum, 2025). Many firms could not afford to switch to sustainable business models since it required considerable investments in the development of new technologies, infrastructure, and suppliers in advance (Green Logistics in 2025, 2025). Varying sustainability laws among countries and regions posed a complex issue in terms of managing the global supply chains and compliance with the same, which complicated the use of uniform sustainable practices (Green Logistics in 2025, 2025). Some omnichannel scenarios have presented a problem of balancing operational efficiency, cost-effectiveness, and environmental objectives, with some of them leading to higher profitability but also possibly to a rise in carbon emissions, and, therefore, context-based decision-making is necessary (Integrating Sustainability in Green Supply Chains, 2025). Inadequate visibility and data silos also complicated the capacity of the companies to recognize sustainability risks and opportunities and restricted the effectiveness of decision-making (World Economic Forum, 2025). Sustainable business models needed to be implemented and this necessitated the fundamental shifts in the supply chain processes, relationships with the suppliers, and product design, which faced some opposition and needed a serious organizational change (Supply Chain Tech News, 2025). To meet sustainability objectives, different stakeholders such as suppliers, logistics providers, regulators, and customers were required to cooperate but it could not always be achieved since stakeholders had different priorities and capabilities (Green Logistics in 2025, 2025). The continuous improvement and transparency were also issues since the standardized, actionable metrics to evaluate the performance of green supply chains were still a challenge (World Economic Forum, 2025). Sustainable supply chains were forced to make trade-offs between minimization of environmental burdens and profitability and this necessitated complex modeling and planning (Integrating Sustainability in Green Supply Chains, 2025). Finally, the use of the latest technologies, such as blockchain, AI, and IoT, essential to sustainable supply chains, was hindered by such factors as cost, technical knowledge deficiency, and complexity of integration (Green Logistics in 2025, 2025).

The emergence of the need of businesses to cope with the environmental issues, the growing pressure of consumers and regulators regarding sustainability and the need of organizations to implement sustainable business models (SBMs) have created an urgent need to consider the topic. Nevertheless, although most companies have done their part to incorporate the concept of sustainability in their activities, there is a major lack of information on how these models can be effectively implemented to improve the performance of green supply chains. The capability to streamline sustainability operations at the various levels of the global supply chain is essential as the supply chain grows in complexity. The issue, thus, is that corporations tend to find it difficult to establish and put into practice SBMs that are not only the sources of environmental and social value but also lead to operational efficiency, resilience, and long-term competitiveness in the supply chain. The research has great relevancy because it seeks to fill this gap by giving an insight on how SBMs can be strategically deployed to improve the performance of green supply chain such that all businesses can achieve their sustainability goals and still operate excellently and remain profitable.

1.1 Research Objectives

To explore the influence of sustainable business model design on green supply chain performance.

To investigate the integration of advanced technologies in enhancing supply chain transparency and efficiency.

To examine the impact of environmental impact reduction strategies on supply chain performance.

To explore factors contributing to supply chain resilience within sustainable business models.

To develop and assess metrics for evaluating sustainable business models in green supply chains using text analytics.

With the objectives of the research outlined and the major areas of interest identified, the following step to be followed in this study will be to search into the body of knowledge that has been developed on the issues of sustainable business models and green supply chain performance. The literature review will provide a comprehensive examination of relevant theories, frameworks, and prior research to contextualize the study's approach and methodology. This section will establish a background of the complexity of the issues related to improving the performance of green supply chain through sustainable business models by going through some important concepts of sustainability, circular economy principles, technological integration and supply chain resilience. It will also identify gaps in literature which will be filled by this research by providing information on the existing situation in the field.

2. Literature Review

2.1 Sustainable Business Models and Green Supply Chains

Sustainable Business Models (SBMs) are created in such a way that they can incorporate the environment, social and economic factors into business operations. These models do not only promote the ecological well-being but also concentrate on generating long-term value to businesses. When implemented in green supply chains, SBMs will help in reducing environmental effects, operational efficiency and profitability. The shift of the conventional linear version of supply chain management to the sustainable, circular version has been very vital in the modern supply chain management. The ideas mentioned in the recent studies are merged in the current literature review to identify the effect of SBMs on the green supply chain performance with the particular focus on the issues of resource optimization, reduction of waste, control of emissions, and resilience.

Some of the basic structures are among them, which are helpful as regards to the impact of SBMs on the performance of green supply chain. Barney (1991) came up with the Resource-Based View (RBV) that emphasized on the utilization of the unique resources as one of the means to construct competitive advantage. In green supply chain, the companies will be in a position to utilize their resources effectively through the application of SBMs that can help in environmental sustainability such as energy efficiency and resources optimization. Additionally, Freeman's (1984) Stakeholder Theory highlights the importance of balancing the interests of stakeholders, including suppliers, customers, and regulators, in SBM design. The strategy will ensure that business activities are aligned to the objectives of environmental sustainability and this will result into enhanced performance of the green supply chain.

Triple Bottom Line (TBL) model, introduced by Elkington (1997) is a way of measuring the business performance in aspects of economic, environmental and social performance. This model supports the fact that organizations are able to improve on their overall performances through the use of SBMs that consider the sustainability in the supply chain operations in order to strike the balance between the environmental protection and profitability. Similarly, DiMaggio and Powell's (1983) Institutional Theory posits that businesses adopt certain practices due to external pressures from regulations and societal expectations. The institutional pressures in the scenario of green supply chains compel the companies to adopt sustainable business models which do not go beyond the environmental laws and requirements of the consumers to become green. Lastly, Circular Economy (CE) model promoted by Kirchherr et al. (2017) concentrates on efficiency of resources, minimization of waste, and products lifecycle management. Incorporation of the concept of the circular economy in SBMs will enable the firms to optimize the use of resources, reduce wastage and increase the environmental performance of the supply chains.

The recent studies have indicated several dimensions in which the implementation of SBMs positively affect the green supply chain performance. The reduction of the impact on the environment is among the principal benefits. The SBMs that focus on optimization of the resources and minimization of the wastes lead to huge benefits to environment. As an illustration, the companies that incorporate the principles of the circular economy into their supply chains see the number of waste materials, energy, and carbon emissions reduced, which enhances their environmental performance (Green Logistics in 2025, 2025). These models are able to improve environmental stewardship by integrating the business goals with sustainability goals thereby ensuring profitability.

It is also essential to ensure the implementation of the latest technologies, including blockchain, AI, and IoT that would enhance supply chain transparency, traceability, and efficiency (Green Logistics in 2025, 2025). The technologies assist companies in complying with regulations and attaining sustainability objectives since they enable the better monitoring of carbon emissions and logistics operations. The other advantage of SBMs is that there is improved collaboration between stakeholders. The implementation may involve collaboration of different stakeholders such as the suppliers and logistics providers as well as the customers. This joint effort enhances resilience in green supply chains because it guarantees that the goals related to sustainability are integrated into all levels of supply chains. The cooperation with stakeholders is the key in addressing the barriers to sustainability, including regional regulations that could be different and the organizational resistance to changes (Supply Chain Tech News, 2025).

Moreover, green supply chains which are integrated with a sustainable business model are more sustainable and profitable. Concentrating on sustainability, the business reduces such risks as the lack of resources or their disruption, which results in long-term stability in the supply chain. At the same time, green practices have the potential of reducing operating expenses and enhancing effective performance, thus leading to financial sustainability (World Economic Forum, 2025). Although the advantages of SBMs in green supply chains are plenty, the process of shifting to SBMs has its difficulties. These are high upfront investment requirements, the fact that it requires a lot of technological infrastructure to be in place and the fact that it is complex to align the sustainability objectives with the business objectives. The reluctance to change in organizations and the fact that sustainability metrics are very difficult to measure also add to the inability to effectively implement SBMs (Green Logistics in 2025, 2025).

2.2 Alignment of a company's business model with sustainability

Sustainability has emerged as a business core goal in the global business environment as it has not only affected the corporate social responsibility but also the dynamics of the supply chains. Convergence of business models to sustainability objectives is becoming one of the critical sources of environmental and operational gains in the supply chain. In this review, the author will look at the recent literature on the impact of strategic incorporation of sustainability goals in business models on supply chain performance, in terms of environmental and operational performance.

Aligning a company's business model with sustainability goals can significantly reduce the environmental footprint of its supply chain. To illustrate, the firms that use the principles of the circular economy (CE) and the environmental innovations such as recycling and energy efficiency improve their environmental performance in the sense of reduction of carbon emissions and waste generation (Hassan, 2025). Implementation of the concept of CE in the supply chain processes has a direct contribution in the conservation of resources and also in reduction of pollution and this implies that businesses are able to not only reduce their environmental impact but also become more sustainable.

Moreover, supply chain tends to be transparent and efficient once the sustainability targets are incorporated in the business models. Companies which implement high-tech solutions to monitor and enhance sustainability reporting, including blockchain and AI, also report higher profits, including the improved management of resources, prediction of maintenance, and efficient logistics (Adewale et al., 2024). Such technologies do not only have the potential to improve the environmental performance of the supply chain but also cause cost savings and efficient operations, which is one more sign of how sustainability and efficiency may be combined.

Research also suggests that aligning business models with sustainability objectives enhances a company's reputation and strengthens its risk management strategies. Multinational corporations (MNCs) using sustainable procurement strategy and Environmental, Social, and Governance (ESG) frameworks and attaining a competitive advantage are more trusted by stakeholders (Basiru et al., 2025). Such convergence will help in curbing the risks posed by regulatory advancements, consumer needs and supply chain shocks, and sustainability is a key element of long-term resiliency of a company.

In addition, the sustainability-based business models, where one takes into account the maximization of resources, tend to lead to the enhancement of operations. Companies which apply sustainability in their supply chain activities such as reduction of wastes and maximization of energy use are more efficient and cost effective in their activities. The study indicates that these models do not only help companies to meet the environmental objectives but also the profitability ones as the case of the successful adoption of the circular economy practices by the big food and FMCG companies shows (Adewale et al., 2024). This is the two-fold advantage of having business models aligned with sustainability; operational and environmental enhancement.

Making business models sustainable also enhances the resilience of the supply chains. The long-term sustainability approach also allows companies to minimize the risks of disruptions, i.e., shortage of resources or changes in regulations. Research has demonstrated that the integration of sustainability can increase the risk management approaches and also develop better relationships with the suppliers and other stakeholders, which will help in building more flexible and robust supply chains (Savi et al., 2025).

Even though it is clear that the inclusion of the sustainability goals in the business models is a money making concept, some barriers exist that do not allow it to happen. They include high initial cost of sustainable technologies, the sophistication of the global supply chains in the many regulatory requirements, and the organization resistance to change (Hassan, 2025). In addition, to date there is still no standard measure of sustainability, and the fact that the direct correlation between sustainability and financial performance has not been quantified is still a significant drawback of most companies (Lutzer et al., 2024). The above challenges highlight the need to enhance more innovation and collaboration in order to phase out barriers to sustainability alignment in supply chains.

2.3 **The Role of Blockchain, AI, and IoT in Improving Transparency and Traceability within Green Supply Chains**

Since sustainability has been an increasingly attractive element, supply chains are increasingly becoming interested in the effects they have on the environment with respect to efficiency. It has been mentioned that one of the factors that contribute to transparency and traceability in the supply chains is the application of blockchain, artificial intelligence (AI), and the Internet of Things (IoT) technologies. These technologies allow real time tracking, data integrity and decision making and all these factors are relevant in coming up with effective and sustainable green supply chains. The recent literature review is summarized here which focused on blockchain, AI, and IoT as the most important contributors to the improvement of sustainability in supply chains regarding transparency and traceability.

The blockchain is relevant in making the green supply chains to be more transparent and traceable. Its immutable and decentralized ledger ensures that all the transactions are securely recorded hence providing all the stakeholders with a transparent and verifiable track data. This reduces the chances of fraud and misrepresentation, particularly in the case of such industries as food, fashion and pharmaceutics, where traceability is the main factor in maintaining trust and compliance (Sawant et al., 2023). The second potential use case of blockchain is the opportunity to enhance the monitoring of the source and path of each product in real-time, which is especially applicable to such sectors as agriculture and renewable energy, where the authenticity of the products and the ethical supply chain must be verified (Onukwulu et al., 2022). To provide another example, it is possible to utilize blockchain to guarantee food safety in its agricultural supply chain, where the stakeholders will be able to identify and resolve the contamination or the fraud in a short period of time (Singh & Singh, 2020). Besides, blockchain contributes to the efficiency of supply chain, eliminating the middlemen and reducing the paperwork, making the verification process of orders and payment more efficient, reduces the delays and costs, and makes the operations more efficient (Shankaran, 2024).

The IoT technologies also play the role of enhancing efficiency and transparency of operations. The IoT sensors will be necessary to monitor the supply chain process in real-time because they will provide valuable information that will help to monitor the status and position of the products in the supply chain. The idea of IoT-based temperature monitoring systems is applicable in the industry where the products are perishable like in the food industry where the products are stored in the most favorable conditions and transported to the final destination, which reduces the waste and makes them more sustainable (Rui & Sundram, 2024). Moreover, IoT can be employed in optimising the utilisation of resources and consumption of energy since it will be capable of gathering and analysing the data at all times to determine the points of inefficiencies. This will help the companies to minimize the amount of energy consumed, wastage as well as carbon emission which helps in the sustainability of the environment (Farazi, 2024). In addition, IoT devices assist in providing valuable information that leads to the prediction of demand, logistics, and inventory. Such evidence-based decision-making can be effective to enhance the efficiency of the supply chain by achieving the efficient distribution of resources, reduced cost of operation and reduced environmental degradation (Singh & Singh, 2020).

Artificial Intelligence (AI) also enhances the green supply chains in terms of traceability and decision making. Artificial intelligence algorithms can be applied to analyse a lot of data to provide more accurate predictions. In the framework of green supply chains, AI is employed to predict the fluctuation in demand, control the inventory, and forecast the resource requirements which is of benefit to more sustainable and efficient supply chain activity (Rahman Farazi, 2024). AI is also useful in enhancing decision-making since it analyses data on IoT devices and blockchain systems. It can examine the performance of different suppliers, predict the possibility of disruption in the supply and recommend most sustainable methods of procurement. This will assist the companies to make more wise decisions, which are environmental friendly (Priyanshu et al., 2024). In addition, the AI algorithms would also have the opportunity to optimize the use of resources by identifying some patterns that would assist in the reduction of the waste and increase the efficiency, which would also lead to sustainable practices, such as the less use of energy, more efficient transport system, and the less usage of raw materials (Farazi, 2024).

The synergies created between blockchain, IoT, and AI are also quite powerful and will enhance the traceability, transparency, and efficiency of the green supply chains. Blockchain makes sure that the information is authentic and clear, and IoT promises to keep track of what is going on in the supply chain in real-time. AI helps process such data to make better decisions and distribute resources, so that the sustainability goals can be achieved with maximum efficiency. As an example, IoT-enabled sensors connected with AI-based predictive maintenance algorithms and blockchain-based tracking systems could be used in the renewable energy industry to maximize energy generation and distribution and guarantee that the process meets sustainability requirements (Onukwulu et al., 2023). This integration does not only enhance efficiency of operation but also leads to more environmental sustainability due to less waste of energy and more management of resources.

2.4 **The Influence of Advanced Technologies on Operational Efficiency and Environmental Impact Reduction in Sustainable Supply Chains**

The development of high technologies like Artificial Intelligence (AI), the Internet of Things (IoT), blockchain has already become one of the crucial elements of changing the supply chain management into something more sustainable. Such technologies would assist the organizations in streamlining the processes, cutting down on their operations cost, as well as minimizing their environmental impact. This literature review is a compilation of the latest scientific articles concerning the effects of these high technologies on the efficiency of the operations and environmental sustainability of the supply chains.

It has been quoted that AI will disrupt the efficiency of the operations as well as the environmental sustainability. One of the spheres of the impact of AI is optimization of operations and management of resources. The AI-based machine learning models can be used to predict the demand with a high rate of accuracy, which can allow the businesses to allocate the resources efficiently, reduce the wastage, and align the production with the current demand (Hasan et al., 2024). It reduces unnecessary production and consumption of resources and this automatically eradicates environmental footprints because there is minimal wastage of material and energy. In addition, AI can improve the efficiency of the transportation logistics by means of routing and scheduling. The AI algorithms have the capabilities to work with enormous quantities of data to establish the most fuel-efficient routes, which reduces transportation time and carbon emissions (Gupta et al., 2023). This goes a long way in the mitigation of carbon footprint of the supply chains. Green supply chains are also achieved through artificial intelligence (AI) that increases the process of managing energy and reducing waste. The inefficiency in energy use can be determined by using AI systems, and certain solutions to the problem can be provided, which will lead to savings of energy and reducing the overall burden on the environment (Gupta et al., 2023).

The supply chain is also more transparent and environmentally efficient owing to the IoT technologies as they allow to monitor the process of the supply chain in real-time. The environmental indicators such as the energy consumption and emissions could also be supervised with the help of IoT and then optimised to reduce the ecological footprint (Enyejo et al., 2024). This real-time visibility contributes towards the effective utilization of the resources, inventory management and effectiveness of transport. Moreover, IoT enables gathering and processing of the data, and thus a business is able to make informed decisions about the activities of their supply chain. This evidence-based decision-making will help it to cut wastes, maximize energy consumption, and improve the management of resources in general, which are the most important ways to achieving

sustainable supply chains (Raziq et al., 2025). The introduction of the practices of circular economy with the assistance of IoT is also feasible in the sense that the life cycle of products can be traced more easily, and, therefore, they can be reused, and the waste can be minimized, which will help to reduce the impact on the environment as the result of the effective recovery and recycling of the resources (Enyejo et al., 2024).

The blockchain technology can be applied in enhancing the openness as well as the environmental accountability of the supply chains. Blockchain's immutable, decentralized ledger ensures that all stakeholders can trace product origins, movements, and environmental impact, which is particularly crucial in industries where provenance and ethical sourcing are critical (Onukwulu et al., 2023). Blockchain is also able to make the supply chains comply with the sustainability requirements due to transparency. Moreover, blockchain reduces frauds and errors since it stores a record of the money transactions permanently. This is important in such industries as agriculture and food production where one needs to make sure that there is genuineness of products and environmental certification. The next means through which blockchain would lead to a more environmentally responsible approach is the ability to track carbon footprint and energy consumption along the supply chain (Santos & Ramoz, 2023). Furthermore, blockchain's ability to facilitate smart contracts can automate compliance with sustainability targets. To cite an example, the suppliers could be made to comply with some environmental standards and only then the payments could be made with the help of smart contracts, which would create a culture of sustainability in the supply chain (Shankaran, 2024).

Sustainable manufacturing and energy systems also have significance in the use of IoT, AI and blockchain technologies. The technologies are used in the improved handling of energy and reduction of carbon emission in the energy supply chains. As an example, real-time tracking of data in the oil and gas sector will enable optimizing the consumption of energy and reducing waste, and predictive maintenance using AI will ensure that no inefficient work of energy systems occurs. Through blockchain, it is simple to be open and comply with sustainability policies (Onukwulu et al., 2023). The manufacturing industry is also developing eco-products with the assistance of AI and IoT, which leads to a reduction in the number of wastes, energy consumption, and emissions. These technologies will be combined, and due to this fact, resources will be exploited more, which will be useful both to the environment and the economy (Sahoo et al., 2024). Furthermore, AI and IoT improve the supply chain network to ensure that transportation and warehouse management becomes efficient. Electric cars, renewable energy, and intelligent routing algorithms help constitute a more environmentally friendly energy supply chain, as well as reduce carbon emissions (Onukwulu et al., 2022).

2.5 Environmental reduction strategies within the green supply chains and its impact on performance

As the number of environmental issues is growing, green supply chain practices are becoming more frequent in business in order to reduce the ecological impact of the business. Green supply chains are oriented to implementation of sustainable activities in the supply chain such as input of materials, production and distribution. The review focuses on some of the key strategies applied in green supply chains in order to reduce the impact on the environment and the effect of the strategies on the performance of the supply chain in terms of operation efficiency, financial performance as well as customer satisfaction.

One of the strategies of the green supply chains is green sourcing and sustainable procurement. This plan involves selection of suppliers based on their performance on the environment and sustainability measures. Another way in which the companies can reduce the carbon footprint and wastage of the extraction of raw materials and production is by ensuring the priority is given to the environmentally-friendly materials and suppliers that are sustainable. It was also established that green sourcing has advantages to the environment and contributes to the achievement of a greater supply chain resilience and risk management (Al-Mahdi et al., 2024). This will lead to the long term reduction of expenses and enhancement of corporate image of a firm due to its friendly nature to the environment.

Another important strategy that is at the heart of the green supply chains is reduction and recycling of the wastes. More companies are embracing the lean manufacturing process and the tenets of circular economy to reduce the amount of waste produced. There is use of recycled materials in the production processes and the packaging waste is minimized by designing innovations. Such practices directly lead to the reduction of landfill, energy, and emissions, thereby leading to environmental sustainability as well as cost-saving in operations (Ahmad et al., 2022). Companies can also improve the efficiency of resources in use by minimizing the waste material and this, in effect, has a positive influence on the overall performance of the company.

The green supply chains aim at minimizing the environmental consequences of logistics operations in energy-efficient transportation and logistics. Such strategies like route optimization, use of energy efficient vehicles and alternative fuels are entering into the mainstream. Not only do these activities decrease the emission of carbon as well as the use of fuel but also the transportation cost is lowered. Research indicates that organizations that employ green logistics initiatives reduce their carbon emissions besides boosting delivery services, customer satisfaction, and supply chain responsiveness (Han & Huo, 2020).

Green supply chains also use eco-design and product lifecycle management as part of the strategy. Eco-design is the design of products with a minimum impact on the environment in their entire life cycle e.g. the use of sustainable material, the ease of recycling the product, and the use of less energy when using the product. The companies that implement eco-design in its product development strategy minimize waste, and at the same

time, attract environmentally-friendly buyers. Such strategies are known to enhance environmental performance and eventually result in the cost savings in the long-term, especially in the automotive and electronics industries (Ahmad et al., 2022).

Lastly, green information system and technology integration is critical to green supply chains success. Such technologies as IoT and blockchain allow companies to monitor and control their environmental impact in real-time. Green information systems, e.g. energy management system and environmental monitoring tools, make supply chains more transparent and traceable, and make sure that products are sourced, produced, and delivered in a sustainable way. These are the technologies that not only minimize the operational inefficiency but also increase the sustainability compliance and reporting, which, respectively, contributes to the corporate image improvement and the attraction of environmental-friendly consumers (Zhang et al., 2017).

The impacts of such green supply chain strategies are experienced in most of the areas of supply chain performance. Regarding the performance on the environmental front, the green supply chain practices make a direct contribution to the minimization of the environmental footprint of a firm. Application of such strategies as green sourcing, waste reduction and eco-design can help the firms to cut down carbon emission, water consumption and wastes. Such cuts often lead to an improved regulatory compliance, which further boosts the image and competitiveness of the company in the market that is more and more interested in sustainability (Zhang et al., 2017; Yang et al., 2025).

The costs associated with the environmental impact reduction strategies can be linked to the economical aspect of operations and their financial performance through the energy efficiency, minimization of the waste, and the logistics optimization. The supply chain activities that are green especially some of the activities that are developed in the area of energy efficient transportation and waste management are able to increase the utilization of resources and reduce the cost of operation. It has been demonstrated that firms which have adopted green practices stand a better chance of succeeding economically due to the low operation costs and resource consumption besides customer loyalty (Han & Huo, 2020; Al-Mahdi et al., 2024).

Brand loyalty and customer satisfaction is also attained by implementing sustainable practices. The companies, whose supply chain is more oriented on the environmental goals, are often preferred to the others because of the growing interest of consumers in the environmental impact of the products and services. The companies ought to be in a position to achieve the competitive advantage by making consumer confidence via guaranteed and verifiable sustainability claims (Ahmad et al., 2022).

Also, the regulatory and risk management is a very essential element in the green supply chains. In most green supply chain practices, regulatory pressures are witnessed. Companies which engage in green supply chain practices to make them compliant to the environmental laws are able to minimize the risks of the non compliance. The advantage of the companies is the avoidance of fines, the reduction of the risk of legal disputes, and the enhancement of the market position in the world that has become more environmentally conscious (Shah & Siddiqui, 2019).

2.6 **Balancing Cost-Effectiveness and Environmental Impact Reduction in Green Supply Chains**

The practice of green supply chain management (GSCM) has been initiated by the pressure that is being exerted on businesses so that they take care of environmental sustainability. These are aimed at reducing the effects of the supply chain activities on the environment together with the consideration of the factor of cost-effectiveness. This review is considering the recent studies that have been conducted on how the companies are developing cost effective strategies in their green supply chain and at the same time maintaining that they do not have much impact on the environment.

One of the big strategies of cost-environmental balance is referred to as green sourcing and supplier partnership. The green sourcing is the selection of suppliers based on how they perform to the environment and this is a very crucial strategy in reducing the impact of the environment. With the inclusion of sustainable procurement, the companies are likely to find out that the investments made in the green technologies or suppliers can lead to the long-term cost-saving because of the efficiency, wastes elimination, and the improvement of resource utilization (Adewale et al., 2024). Moreover, the working relationship with the suppliers is close enough to distribute the load of the sustainability initiative, e.g., the necessity to reduce the emission or to launch a recycling program. Such a collaboration will enable the sharing of the expenses and will enable the maximum value of sustainability work through the entire chain (Suwanda, 2024).

The second important strategy is the waste reduction and lean manufacturing. The green supply chain and lean manufacturing will enable companies to reduce wastages and become cost effective. By cutting the non-value-added activities, companies can have an influence on the environment and also by making more efficient use of the materials and energy, cost of production can be cut. This plan aligns with the ideas of circular economy, such as the reuse of the materials and a decline in the amount of waste in the landfills (Ashoka et al., 2023). It has been suggested that the firms that adopt such strategies can increase their bottom line because they also achieve their sustainability goals (Adewale et al., 2024).

The second element of the balance between the environmental sustainability and cost-efficiency is the logistics that is energy efficient. Logistics plays a significant role in environmental performance of supply chain and the cost performance. Some of the measures that cut on emission and transportation costs include streamlining transportation channels, running energy saving cars and embracing green packaging. In the study, it is found that in addition to the carbon footprint of a supply chain being reduced through logistics initiatives such as route optimization and the use of renewable sources of energy, the efficiency of the supply chain also gets boosted by a drop in the transportation cost (Zhang &

Di, 2025). These logistical innovations are not only good to sustainability, but also to profitability.

Product design and eco-innovation also provide the adjustment of the cost-effectiveness and environmental sustainability. The firms are able to reduce costs of production and disposal by designing products that have less environmental impacts such as consumption of less energy in their use or recyclable products. The company can achieve the level of sustainability and maintain cost-effectiveness through such innovations as modular product design or end-of-life management of the products (Adewale et al., 2024).

The second approach that prefers both the environmental performance and cost reduction is the application of digital technologies to sustainability. The digital technologies such as blockchain, AI, or IoT also transform the environmental and cost aspects of the supply chains and enable businesses to manage them. An example can be made of machine learning and AI which can help the companies better anticipate the demand, thereby reducing overproduction and wastes. Blockchain enhances transparency as it ensures that sustainability is upheld throughout the supply chain and this lowers the compliance and monitoring cost. The monitoring of products, energy consumption, and emissions in real time is possible with the assistance of IoT, which results in the optimization of the resource consumption and decrease in wastes (Zhang et al., 2024). The technologies improve the efficiency of operation and they also result in environmental performance and cost savings.

There is also a lot of economic impact of green supply chain practices. Environmental regulations are also important to the green supply chain strategies because of their cost-effectiveness. The regulations on the environment that encourage the businesses to practice green issues include carbon emission cut down rules or waste management requirements. Businesses that are ready to adopt the green approach tend to realize that the initial capital outlay is balanced by operational savings, including energy expenses, disposal of wastes, and enhanced use of resources (Zhang & Di, 2025). Research has found that such regulatory pressures stimulate firms to innovate and discover cost effective methods of compliance, in this case, through the use of cleaner technologies or energy efficient systems that will lower the overall costs in the long run (Adewale et al., 2024).

Finally, green supply chains focus on strategic alliances and long time savings. Green supply chains will usually ask companies to make strategic alliances with suppliers as well as customers who are environmentally friendly. Such alliances are capable of resulting in lower operation costs due to sharing of innovation and economies of scale. The companies who cooperate in green initiatives, e.g. in the areas of joint emission reduction or sustainable sourcing, tend to achieve not only cost savings but also better environmental performance. As an illustration, a joint waste management strategy, or energy consumption one will reduce the costs of all participants and, at the same time, increase the sustainability of the whole supply chain (Adewale et al., 2024).

2.7 Resilience of Supply Chains in the Sustainable Business Models

The importance of resilient supply chains has been on the rise in the recent years especially in the application of sustainable business models. The capability of a supply chain to adjust to the disturbances, recuperate rapidly and keep running despite unexpected problems is known as resilience. As much as the sustainability in the supply chains is important in ensuring viability in the long run, it should be balanced by the need to have flexibility in operations, cost-effectiveness, and risk management. This is the review of the major elements that increase supply chain resilience when establishing sustainable business models.

Integration of technology and Industry 4.0 are important in improving the supply chain resilience. The implementation of the new technologies, including AI, IoT, blockchain, and big data analytics, are better in real-time monitoring, enabling predictive analytics, and making decisions. Digitalization of supply chains enables businesses to acquire increased visibility, monitor the movements of the supply chains, and detect the risks at an early stage. The technologies of Industry 4.0 also help with sustainability since they optimize the use of resources, minimize wastes, and allow responding to disruptions in an agile manner (El Maalmi et al., 2023). These technologies became particularly useful in such a crisis as the COVID-19 pandemic and helped companies adjust to the changes in the environment and become more flexible and able to recover fast.

The other important strategy to improve resilience in the sustainable supply chains is the diversification of the sources of supply. Through this, sourcing of products and services utilizes more than one supplier and region hence, minimizing risks of over dependence on one supplier and region especially during disruptions like natural calamities or political instabilities. Considering the sustainability of the business models, the procurement of suppliers that have environmental standards is also sustainable in terms of corporate sustainability as it helps to reduce the weaknesses of the supply chain (Kashyap et al., 2024). This kind of diversification will diffuse the risks to various channels and this enables more flexibility in their operations in case of any unexpected disturbances.

Stakeholder engagement and collaboration play a major role in developing resilient supply chains. Good supplier, customer, and other stakeholder relationships help the businesses to be more responsive to the changing market conditions and environmental issues. Teams that engage in joint problem-solving and shared innovative practices assist companies in coping with disruptions. As an illustration, in the context of the COVID-19 crisis, the companies, which collaborated with the suppliers to adjust to the supply shocks, managed to sustain their operations at a smoother level despite the effects of the pandemic (Onwuzulu & Deliperi, 2024). The cooperation also enables the sustainability of the whole supply chain, including the raw materials sourcing to the delivery of the products, which increases the resilience to environmental and operational shocks.

The most basic elements of resilience are agility and flexibility of operations. Organizations that have adopted agile ideas in their supply chain activities like flexibility in production systems and quick response to demand changes are more able to sustain the continuity of the disruptions. Agility enables the business to rapidly adapt to changes in the supply chain strategies based on the changes in the environment or market so that the operations become sustainable (Karanam et al., 2024). The ability to be flexible in logistics, inventory management, and relations with suppliers contributes to the resilience of the supply chain as a whole, and businesses will be able to recover quickly after the disruptions.

The key elements of supply chains resilience are risk management and sustainability practices. The firms should take the initiative to discover and address risks, such as environmental risks, social risks and economic risks. Through green initiatives such as waste minimization, the use of renewable energy, and ethical procurement, companies help to meet the environmental objectives and decrease the business risks of scarcity and compliance. These are forward-looking measures that can assist businesses to manage climate change and other environmental issues related risks and eventually enhance the resilience of their supply chains in the long term (Zhu & Wu, 2022).

Lastly, a resilient supply chain is much dependent on leadership and its culture. The leadership, particularly transformational leadership is crucial to encourage the implementation of sustainable practices and increase resilience. Leaders who focus on sustainable and resilient supply chain promote innovation, cooperation and long term strategic thinking. This creates a culture that is flexible and can respond to changes effectively so that businesses can get back into the normal course in a short period without neglecting the sustainability objectives (Naharuddin & Mokhtar, 2023).

2.8 **Risk Management and Adaptability in Green Supply Chains for Resilience**

As the business environment continues to grow volatile and uncertain, the need to incorporate risk management and adaptability into the green supply chain strategies has become very crucial in enhancing resilience, particularly in environmental and market related challenges. Green business is no longer a luxury that organizations can afford but a requirement in most organizations in their quest to ensure that their operations are environmentally conscious. This review talks about the major aspects that lead to the creation of resilience in green supply chain by integrating risk management and adaptability.

Risk management is very useful to improve the resilience of the green supply chain. The first stage of the process of forming a resilient supply chain involves identification and proactive mitigation of risks. Failure Mode and Effect Analysis (FMEA) and Monte Carlo simulations are among the tools, used in the organizations, to forecast potential disruptions and strategize them beforehand. To provide an example, the COVID-19 pandemic demonstrated the vulnerability of the global supply chains and the necessity of companies to develop pro-active risk mitigation strategies. The firms that had implemented some of the practices of the green supply chain management (GSCM) such as the use of renewable resources and the sourcing of various suppliers had more opportunities to manage the disruptions without compromising the sustainability objectives (Bani-Irshid et al., 2023).

Digitalization of risk monitoring is another crucial concern of enhancing risk management in green supply chains. When such technologies as blockchain, Internet of Things (IoT) and Artificial Intelligence (AI) are combined, they will provide real-time data on the activities within the supply chain, and this data will allow businesses to detect the disruptions in time before they become crucial. As an example, predictive analytics (powered by AI) may predict the interruptions that may be caused by environmental or market fluctuations, and businesses can change their strategies in real-time. Moreover, blockchain enhances traceability and transparency, where sustainability objectives are achieved in combination with the reduction of the risks of fraud and mismanagement (Enyejo et al., 2024).

Practices of circular economy and sustainability also play important roles in the risks management in green supply chains. A circular economy model will make companies less reliant on a volatile market as a source of raw material and will provide a substitute to the usual linear supply chain. Reuse of materials, recycling of products and optimum use of resources not only minimizes the environmental effects, but also minimizes the operation risks. Such sustainable activities enable organizations to be ready to face long-term environmental issues, including the loss of resources and climate change, and, at the same time, enhance their financial stability by saving money and being less dependent on external suppliers (Zavala-Alcívar et al., 2020).

The other important element of resilient green supply chains is adaptability. Operation agility and flexibility are necessary to adopt the changes in the market and environment in a short time. Green supply chains can be agile and allow the companies to make quick changes in their operations and sourcing strategies in order to respond to the external disruptions. As an example, in the pandemic, most companies have shifted their supply chain by going local or changing their suppliers when their trade routes with other countries were shut down. Agile supply chains assist companies in ensuring continuity and still achieving sustainability objectives (Rashid et al., 2023). Also, firms which had flexible systems of production had the advantage of being able to change the different product lines as the demand patterns changed and thus the need to be flexible.

The cooperation and stakeholder involvement are also critical towards increasing resilience. The good relations with suppliers, regulators and customers enable businesses to incorporate flexibility in the supply chain. Companies can become more resilient by exchanging information and working together on projects to be more sustainable. As an illustration, in a period of disruption, organizations that had good relationships with their stakeholders were better placed to solve any challenge.

The green-oriented collaborations aiming at achieving the common green objectives (e.g., reducing carbon emissions or encouraging renewable energy usage) do not only enhance environmental performance but also enhance resilience through continuity and support of each other in times of crisis (Jamaludin et al., 2024).

The concept of sustainability as a source of competitive advantage is also being associated with resilience in green supply chain. Companies which effectively incorporate sustainability initiatives in their business models usually find themselves in a better position to react to customers demands on eco-friendly products, changes in regulations and global environmental issues. Specialising in sustainable procurement, waste minimisation and energy efficient production can make companies highly competitive, and at the same time increasing their long-term resilience. It has been found that companies that embrace sustainability tend to have a greater customer retention rate, better positioning and resilience (Zhu & Wu, 2022).

Green supply chains have demonstrated their resilience in the post-COVID-19 era, which makes them adaptable. During the pandemic, the resilient green supply chains were identified as a necessity to adapt fast to global disturbances. Risk management and adaptability strategies were among the most common ways used by many businesses to counter the disruptions caused by the pandemic, such as redesigning their supply chain networks, transitioning to local suppliers, and becoming sustainable to minimize the effect they have on the environment in the long run. The crisis led to the increased rate of digital solutions and strengthened the demands of businesses to establish agile and sustainable models that could succeed even during difficult periods (Mathiyazhagan et al., 2023).

2.9 Metrics to Measure Sustainability and Performance of Business Models in Green supply chains

Sustainability and performance measurement of green supply chain is critical to the companies that are interested in combining environmental objectives with business performance. The issue that the organizations face when they implement green supply chain management (GSCM) is that they are forced to quantify the environmental performance along with the business performance. The current literature review studies the most appropriate metrics and models that have been set up since 2020 to check the sustainability and performance of business models in green supply chains.

In measuring the sustainability, the priority in the green supply chain is the measurement of the environmental performance. One of the most popular measurements and one of them is the carbon footprint that measures the quantity of greenhouse gases that a supply chain emits. This plays a significant role in the evaluation of environmental impacts of the supply chain activities. The other notable indicators are water consumption and energy efficiency. As it has been shown, energy and water consumption reduction is the crucial factor in the reduction of the ecological footprint, thereby maximizing the degree of sustainability and cost-effectiveness (Sharma et al., 2023; Zhan et al., 2021).

The economic performance of the green business models is usually determined by the use of cost benefit analysis and a measure of returns on investment (ROI) by the organizations. The tools gauge the financial success of the sustainability activities and they help the businesses to determine whether the environmental goals are in alignment with the profitability. The other significant measure is the total cost of ownership (TCO) that is composed of the environmental and the operational cost of obtaining and handling materials. Research has revealed that the operating cost of a business would be reduced over time as the green practices get integrated into the supply chain, particularly in the areas of optimizing the cost of energy and waste management (Ahi, 2021).

The social performance indicators are also turning out to be a major indicator of gauging the overall effect of the green supply chains. The social implication of the green supply chains is determined using indicators such as the welfare of the workers, the ethical issues of the supply chain and the community among others. One of the most well known measures of social benefit of green initiatives is the Social Return on Investment (SROI). Li et al. (2021) emphasize that the social metrics should be added to the equation along with the environmental and economic ones in order to get the complete image of sustainability in supply chains.

Life Cycle Assessment (LCA) is a major tool that can be applied in order to measure the environmental impact of products throughout the whole life span, that is, to the extraction of raw materials as well as to the end of life disposal. LCA and green supply chains together allow businesses to come up with the sustainability performance in a more wholesome manner. Scientists have found out that the application of LCA helps companies to identify the parts of their supply chains that they need to be concerned about, and then they interfere to reduce their impact on the environment (Qorri et al., 2018).

The Multidisciplinary Decision-Making (MCDM) analyses are used to measure the performance of sustainability depending on a number of factors including the Analytical Hierarchy Process (AHP) and Fuzzy Set Theory. Through these methods, organizations are able to introduce a number of measures such as cost, environmental impact and social responsibility in decision-making. Through MCDM, a systematic approach to prioritize and classify the relative importance of different sustainability targets in the activities of a supply chain is provided (Giannakis et al., 2020).

The objects of supply chain resilience measures are the ability of the supply chain to react to the changes e.g. natural disasters, market changes or regulatory changes etc. The supply chain flexibility, risk exposure, and recovery time are the most important resilience indicators that would enable the determination of how far green supply chain will recover following shocks. The resilience in combination with sustainability is a promise that the supply chains will be effective both in the light of environmental problems and when it comes to the market (Sharma et al., 2023).

Some of the models have been developed to gauge green supply chain sustainability. The Triple Bottom Line (TBL) framework is one of the broadest models in which performance is analysed on the grounds of economic, environmental and social performance. It was established that TBL helps in stabilizing the organizations in terms of sustainability and business requirements since TBL does not only consider the economic gains but also the social and environmental implications (Moran et al., 2025).

Green SCOR Model is an improvement of the traditional Supply Chain Operations Reference (SCOR) model which entails adding environment sustainability measures to the normal supply chain operations. The model includes sustainability in the key sectors of its activity, such as sourcing, production, and distribution, which allows evaluating the work of the supply chain more comprehensively and effectively (Stohler et al., 2018).

Sustainability Balanced Scorecard (SBSC) is a modification of the original balanced scorecard which enables incorporation of the sustainability measures into the traditional balanced scorecard model and provides a procedural method of monitoring the environmental and social performance as well as the financial and operations measures. The tool will help the business to track the attainment of the sustainability goals as well as ensure that short term goals are aligned to long term plans on sustainability (Torabizadeh et al., 2013).

2.10 **Utilization of Text Analytics in Analyzing Sustainability Data for Improving Green Supply Chain Performance**

Green supply chain management (GSCM) has remained a significant strategy to organizations that are keen to make insignificant changes to the environment without influencing the economic performance. However, sustainable supply chains are difficult to manage since there are numerous data that are produced in the various activities of supply chains. Text analytics which involves the processing and analysis of text data has emerged as a significant tool to derive useful insights on data related to sustainability. In this literature review, the author talks about the potentiality of applying text analytics to the sustainability data to improve the green supply chain performance.

One of the greatest applications of text analytics in green supply chains is sentiment analysis of the stakeholders. Sentiment analysis applies information in form of text in a source such as social media, customer reviews and sustainability reports to know how the people view the green initiatives of the organization. This type of analysis makes a company understand the issues of the stakeholders and areas that the stakeholders require them to work on in their sustainability strategies. By listening to the stakeholders, the companies may better their performance in the green supply chain and may be more responsive and responsible (Zhu & Wu, 2022).

The other significant area where the text analytics may add value is the sustainability reporting and compliance monitoring. A lot of text-based information is produced by the companies in sustainability reports, regulatory reports and environmental audits. These documents, in turn, can be processed automatically by text analytics, and key sustainability metrics can be extracted and analyzed, particularly on the basis of the natural language processing (NLP) techniques. With such strategy, companies can track the compliance to environmental regulations, measure sustainability performance and track trends in sustainability reporting, thereby reducing manual efforts and attaining transparency (Makhdoom et al., 2024).

Text analytics also enhances risk management and early detecting risks in the environmental environment. Using the information on the environmental risks in news articles, reports of their suppliers, and environmental surveillance systems, companies can determine the potential disruption of their supply chains, such as natural disasters or climate-related risks. Predictive models as an example of text analytics can be deployed to foresee disruptions and vulnerabilities in order to allow businesses to avoid potential risks and become resilient in their green supply chains (Sharma et al., 2023). This type of proactive action helps the companies to be quick in reacting to the environmental threats.

The second critical GSCM area is the assessment of the sustainability performance of GSCM suppliers and in this segment, text analytics can be very useful. Based on the analysis of the public communication, the sustainability reports and the third-party review, the text analytics tools will be able to identify the environmental, social and governance (ESG) performance of suppliers. Application of machine learning algorithms to determine relevant data helps the organizations to make viable sourcing decisions according to the goals of sustainability. This is applied in order to improve on the overall green performance of the supply chain and also to ensure that the suppliers are upholding the necessary level of sustainability (Qahman et al., 2025).

The other place where the text analytics may be useful is in market analysis of the sustainable demand of products. Textual data mining of information that is available in customer review, product description and e-commerce websites can be used by businesses to identify the trends in consumer demand of eco-friendly products. The data helps companies to react to their products, lean their manufacturing process and reduce wastage in the supply chain. In addition, the study of the market performance of the green products may trigger the additional innovations in the field of sustainability (Liao et al., 2023).

Green supply chains are not complete without optimization of green logistics and text analytics may be helpful to improve performance of logistics. The text analytics can be useful in planning the routes, reducing fuel and increasing efficiency of the logistics through the textual information presented in the shipment logs, weather reports and traffic data. It is also able to monitor the impacts to the environment that is brought about by the logistics operations such as the emission of carbon in the process of transport and provide feasible suggestions on how the impacts can be reduced (Enyejo et al., 2024). The strategy enables companies to ensure that logistics are greener and cheaper.

Text analytics in the green supply chain management can bring in tremendous advantages. The main benefits

include increased decision-making and strategic planning. Companies can find hidden patterns and correlations in large volumes of textual data and therefore, they can be identified through analysis. Such knowledge enables companies to create more efficient practices of diminishing environmental influence without sacrificing operational performance (Sharma et al., 2023). Moreover, it helps to conduct better sustainability reporting because text analytics can easily extract the necessary metrics in large data and help companies to evaluate their progress on their sustainability initiatives and make sure that they comply with the legal regulations (Zhu & Wu, 2022).

Another advantage of text analytics tool is the real time monitoring and response. Real time monitoring of sustainability performance throughout the supply chain can be achieved by companies which continuously analyze textual information provided by different sources. It enables the businesses to see where there is lagging performance and make corrective measures in time. This active style will make organizations respond better to the modifications in the market and in the environment (Makhdoom et al., 2024).

3. Methodology

3.1 Research Design

In this research, the research design is qualitative and literature review is used to study the subject of sustainable business models and their contribution in improving green supply chain. The research design is appropriate for the study's objective, as it aims to gather in-depth insights into the factors and strategies that contribute to effective sustainable business models in the context of green supply chains. The study will aim to capture an overall picture of the drivers of green supply chain performance through a synthesis of the results of academic articles, industry reports, and case studies on the topic of sustainability practices, technology integration, and resilience strategies.

3.2 Research Approach

The study is based on the systematic qualitative literature review. Such an approach implies the review of the available scholarly articles, reports, and other literature materials to extract the main themes, patterns, and gaps in the literature. Through this review, the study will aim at summarizing existing information on sustainable business models, how they fit in supply chains, and the contribution of technologies and environmental strategies. This method would assist in determining some frameworks, theories, and the gaps that can be used to conduct further studies and practice knowledge in sustainable supply chain management.

3.3 Research Philosophy

The study adopts the interpretivist philosophy of research, which assumes that knowledge is a social construct and it is best comprehended by the meanings that the individuals or organizations give to their experiences. The interpretivist perspective will be suitable since the study aims at investigating how sustainable business models affect the green supply chain performance. It enables the researcher to pay attention to the subjective and contextual image of sustainability practices and the way of perception and implementation of these practices in various sectors. This school of thought is also guided by the need to realize the complexities and delicate interrelations of various elements of the green supply chain.

3.4 Data Collection

The information was gathered by carrying out a comprehensive literature search in academic journals, books, industry reports, and other sources of publications. The criteria used in selecting literature were inclusion criteria to be used in the selection of the literature based on relevance to the green supply chains, sustainable business models, technological advancements, and environmental impact reduction strategies. The identified literature was further classified into categories by some major themes and concepts like sustainability, resource efficiency, technology integration, resilience, and measures to assess the supply chain performance. Such data was gathered and examined in order to answer the five key research objectives.

3.5 Statistical Methods of Data Analysis

Thematic analysis was used to analyse the data and this method assisted in determining the common themes and patterns in the literature collected. Thematic analysis enabled the analysis of the central aspects of sustainable business models, including sustainability integration into supply chain-related practices, the use of advanced technologies, and strategies of enhancing efficiency and resilience. Data organization and additional content analysis were performed with the help of NVivo software that allowed quantifying the occurrence of such terms and concepts as sustainability, technologies, and performance metrics. To increase the knowledge about the prominence and the relationships between these concepts, visualizations, such as word clouds or NVivo diagrams, were deployed. Such analytical approaches made it possible to thoroughly analyze the literature, which made it possible to trace the trends, gaps, and areas of future studies in the field of green supply chains.

The research use these qualitative and text-based analysis methods in order to come up with practical knowledge regarding what factors affect the green supply chain performance and what metrics can be used to determine whether sustainable business models are effective.

4. Discussion

4.1 Objective 1: To explore the influence of sustainable business model design on green supply chain performance.

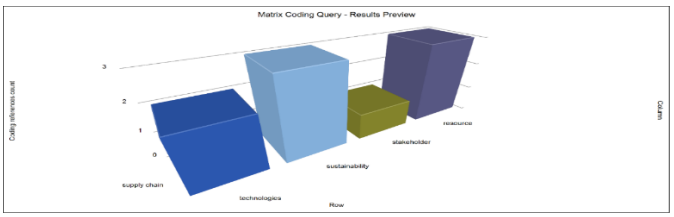

Fig. 1. Matrix Coding Query for sustainable business model design on green supply chain performance.

This NVivo matrix coding query (see Fig. 1) presents the frequency of coding references where the "Row" items,

which likely represent documents or specific coded concepts from the data (not visible as labels in the 3D chart), intersect with the "Column" codes, which correspond to five specific nodes: "supply chain," "technologies," "sustainability," "stakeholder," and "resource." The number of coding references is represented in the height of each bar. The "resource" column has the highest frequency of coding references, exceeding 3, followed by "sustainability," which also shows a high number of references near 3. "Technologies" has a moderate count of around 2, while "supply chain" has a lower count of approximately 1.5, and "stakeholder" has the lowest count, below 1. Despite the absence of explicit references to "business models" or "green performance" in the rows or columns, the relationships observed provide valuable insights. The presence of "supply chain" and "sustainability" as coded columns indicates the inclusion of fundamental components of the research area, with sustainability being a significant focus, suggesting frequent discussions on environmental, social, and economic sustainability in relation to supply chain contexts. The high frequency of "resource" coding indicates that discussions on resource efficiency and management are central, aligning with the emphasis on optimizing resource use, such as energy, raw materials, and waste, in green supply chain performance and sustainable business models. The substantial coding for "technologies" suggests that technological advancements play a significant role in enabling process optimization, waste reduction, and enhanced green outcomes, with potential exploration of how business models integrate technologies for these purposes. Although "stakeholder" shows the lowest count in this query, its presence highlights the importance of stakeholder collaboration in sustainable business models and green supply chains, indicating that while stakeholder engagement may not be as prominent in this query, it remains a crucial factor in the successful implementation and performance enhancement of these models.

Fig. 2. Word cloud for sustainable business model design on green supply chain performance

This word cloud (see Fig. 2) is a visualization of the terms most used in text data, and the larger the font size the more frequent the term is. The most prominent terms, including "supply," "sustainability," "green," "chain," "environmental," and "performance," directly align with the core components of research objective, highlighting that data extensively covers the central themes of study on green supply chain performance. Terms such as "businesses," "companies," "models," and "strategies" reflect a focus on the organizational aspects of sustainable business model design, underscoring how companies structure their operations to achieve sustainable and green outcomes. The emphasis on "performance," "efficiency," "enhancing," "impact," and "reduction" further illustrates the data's concern with improving supply chain outcomes through sustainable practices. Additionally, the prominence of "technologies" and "resource" suggests that these factors significantly influence green supply chain performance, aligning with objective to explore their impact. The inclusion of terms like "logistics," "operational," "practices," "risk," "traceability," "compliance," and "stakeholder" indicates that the data provides a comprehensive view of green supply chain management, addressing operational, regulatory, and relational aspects. Furthermore, the presence of terms such as "metrics" and "analytics" points to a discussion around the measurement and analysis of performance, which is essential for assessing the effectiveness of sustainable initiatives. On the whole, the word cloud gives solid grounds to believe that corpus is very relevant and rich to reach research aim of studying the impact of sustainable business model design on the green supply chain performance.

4.2 Objective 2: To investigate the integration of advanced technologies in enhancing supply chain transparency and efficiency.

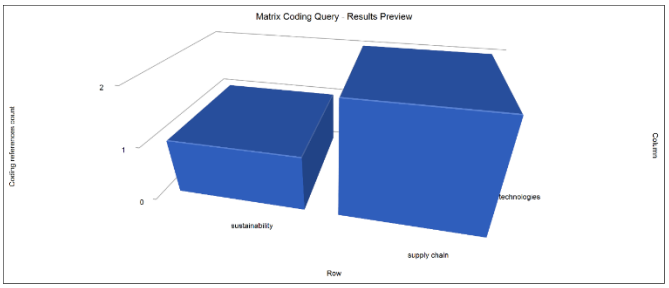

Fig. 3. Matrix Coding Query for advanced technologies in enhancing supply chain transparency and efficiency.

This NVivo matrix coding query (see Fig. 3) presents a 3D bar chart that illustrates the count of coding references for specified "Row" nodes against "Column" nodes. The columns correspond to "sustainability" and "technologies," while the rows include "supply chain" (along with potentially other unnamed rows represented by the different bars for each column). The height of each bar indicates the number of coding references, with the "supply chain" row (the forward-most bar in each pair) showing a higher count for "technologies" (approximately 2) than for "sustainability" (approximately 1.5). The second row, behind the "supply chain" bar for each column, also displays coding, but its relevance is unclear without knowing the specific row it represents. This matrix question is more closely related to research aim in the context of the study of the introduction of innovative technologies in the development of the supply chain transparency and efficiency. The matrix explicitly cross-references "supply chain" with "technologies" and "sustainability," directly addressing key components of

study. The higher coding reference count for "technologies" in relation to "supply chain" suggests substantial discussion on the application and integration of technologies within supply chains, supporting objective of investigating "the integration of advanced technologies." While "technologies" has a higher count, the presence of notable coding references for "sustainability" indicates that technology integration is frequently discussed within the context of sustainable practices, aligning with the inherent connection to "green supply chains." Although "transparency" and "efficiency" are not directly represented in the matrix, the strong co-occurrence of "supply chain" and "technologies" implies that the integration of these technologies is likely aimed at enhancing transparency and efficiency, which are commonly sought outcomes in the adoption of technologies in supply chains.

Fig. 4. Word Cloud Query for advanced technologies in enhancing supply chain transparency and efficiency

The word cloud is a visual display of the terms frequency in textual data, where the bigger font size means the higher frequency (see Fig. 4). The most prominent terms include "supply," which is the dominant term, highlighting its central role in data, and "chain," which almost always co-occurs with "supply" to form "supply chain." "Technologies" is extremely large, directly reflecting objective's focus on "advanced technologies," while "efficiency" and "transparency" are both very prominent, aligning closely with goal of enhancing these aspects. Other significant terms include "environmental," which suggests a connection to sustainable practices, and "energy," indicating a focus on energy consumption or management. Specific advanced technologies such as "blockchain" and "IoT" are also highly visible, indicating their frequent mention in data. Additionally, "data" appears prominently, emphasizing its essential role in leveraging technologies to enhance transparency and efficiency. Moderately sized terms like "logistics," "management," "optimizing," and "reducing" reflect operational aspects of the supply chain and the goal of improving performance. Other terms like traceability, systems, advanced and integration are also remarkable, and this indicates the integration of these technologies and their use in the supply chains. The existence of such words as renewable, risks, and fraud implies that data also focuses on the sustainability, the threats to transparency, and the ways to reduce the risks with the help of technology. This word cloud is quite convincing visual proof that qualitative data is very pertinent to the following research objective, "To examine the incorporation of the advanced technologies in improving the supply chain transparency and efficiency." The fact that such terms as supply, chain, technologies, transparency and efficiency are mentioned, proves that data are directly related to the main themes of research. Also, the fact that the term of blockchain and IoT are mentioned as significant features shows that the particular attention is paid to the technologies that are implemented into the supply chains, and this can be regarded as the evidence that can be explored to find out more about their contribution to the transparency and efficiency of supply chains. The focus on the results in the form of efficiency, transparency, enhancing, and optimizing also confirms the aim of enhancing the supply chain performance. The high occurrence of the word data indicates its significance as a factor that contributes to transparency and efficiency, whereas the mention of environmental and energy indicates that the technology integration is also viewed through the prism of sustainability, which is an extra dimension of information that can be of interest to research.

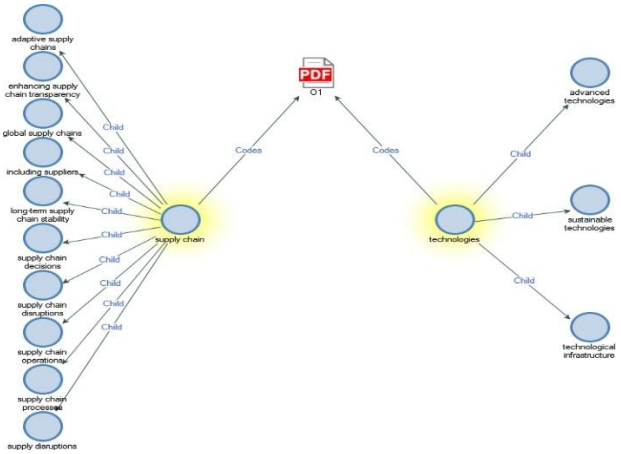

Fig. 5. Comparison diagram between supply chain and technology

This image represents an NVivo "Comparison diagram" or concept map, illustrating the relationships between various nodes and a central document (see Fig. 5). The central elements include the PDF icon (O1), likely representing the source document or a collection of documents from which the coding was derived, and two prominent nodes: "supply chain" and "technologies," both directly connected to "O1" via "Codes," signifying that these concepts are major themes within the source data. The "supply chain" node has several child nodes, such as "adaptive supply chains," "enhancing supply chain transparency" (which directly relates to the objective of enhancing transparency), "global supply chains," "including suppliers," "long-term supply chain stability," "supply chain decisions," "supply chain disruptions," "supply chain operations," and "supply chain processes." These sub-themes touch on a wide scope of issues pertaining to supply chains such as operations, issues and strategic objectives. Similarly, the "technologies" node has child nodes like "advanced technologies," "sustainable technologies," and "technological

infrastructure," highlighting the data's focus not only on the presence of technologies but also on their specific types and the underlying infrastructure necessary for their integration. Within the framework of the study of the integration of innovative technologies in the improvement of transparency and efficiency in the supply chain, this diagram presents significant evidence that the data correspond to the objective of research. The explicit mention of "enhancing supply chain transparency" and "advanced technologies" directly ties to key components of the objective, with the former linking to transparency improvements and the latter focusing on the specific type of technologies under investigation. Although "efficiency" is not directly represented as a child node, the inclusion of "enhancing supply chain transparency" implicitly suggests an improvement in efficiency, as better transparency often leads to more efficient supply chain operations. The scope of supply chain focus and the technological specific situations reveal that the data will offer an in-depth discussion of integration of technologies in supply chains, which is the primary objective of research.

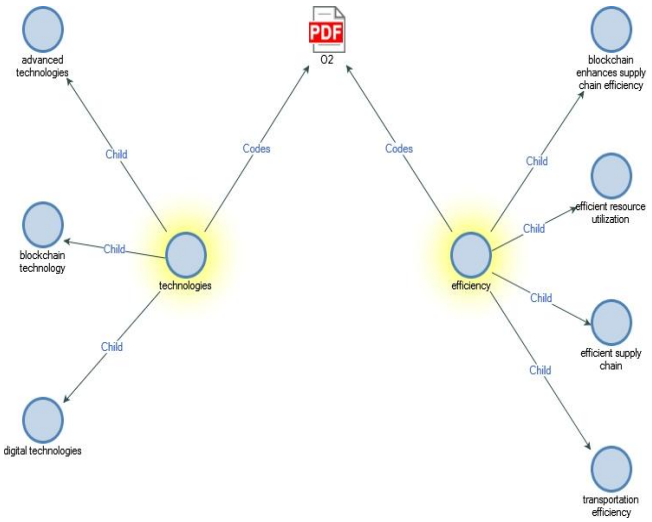

Fig. 6. Comparison diagram between technology and Efficiency

In this diagram (see Fig. 6) there are the relationships between the key concepts or nodes and a central document (O2) and the central element is the PDF icon (O2), which is the source document(s) where the coded information is obtained. The diagram features two major nodes: "technologies" and "efficiency," both directly connected to "O2" via "Codes," indicating that these are significant themes in the source data. The "technologies" node has several child nodes, including "advanced technologies," "blockchain technology," and "digital technologies," suggesting a focus on specific types of technologies discussed in the data. Similarly, the "efficiency" node includes child nodes such as "blockchain enhances supply chain efficiency," "efficient resource utilization," "efficient supply chain," and "transportation efficiency," providing insight into various ways efficiency is enhanced in supply chain contexts. This diagram has a powerful and definite contribution to make when it comes to the exploration of how advanced technologies can be used to increase the transparency and efficiency of the supply chain. The direct inclusion of "advanced technologies" under "technologies" aligns with the focus of research, while the child nodes under "efficiency," particularly "blockchain enhances supply chain efficiency," show a clear connection between specific technologies and their impact on efficiency. Although "transparency" is not explicitly represented, the association of "blockchain technology" with enhanced supply chain transparency suggests that this theme is implicitly addressed. The diagram also highlights the use of some technologies such as blockchain in realizing efficiency, and this aspect presents convincing arguments that the integration of efficient technologies in enhancing efficiency is one of the main themes in data. Furthermore, the varied dimensions on which efficiency has been studied, right from the use of resources to the transportation, point to a multidimensional perspective of the study of efficiency in the supply chain.

4.3 Objective 3: To examine the impact of environmental impact reduction strategies on supply chain performance.

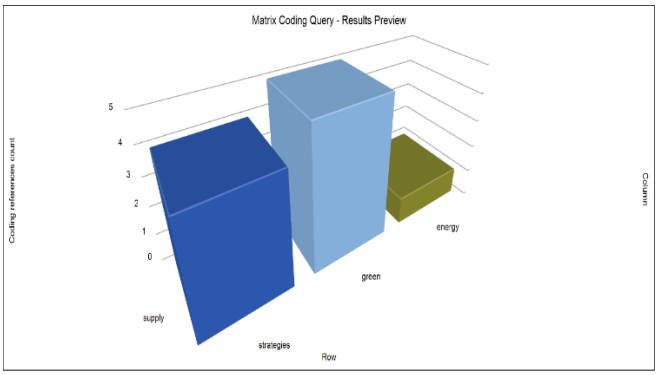

Fig. 7. Matrix Coding Query for impact of environmental impact reduction strategies on supply chain performance

This NVivo matrix coding query (see Fig. 7) displays a 3D bar chart illustrating the coding reference count for specified "Row" nodes against "Column" nodes, with columns representing "green" and "energy" and rows representing "supply" and "strategies." The height of each bar indicates the number of coding references where a "Row" node was coded with a "Column" node. From the visual representation, the intersection of "strategies" and "green" shows the highest number of coding references, exceeding 5, followed by the intersection of "supply" and "green" with close to 4 references. The intersection of "strategies" and "energy" has a moderate count of approximately 3.5, while the intersection of "supply" and "energy" has the lowest count, below 1. This matrix question is very relevant in the context of the investigation of the effect of environmental impact reduction strategies on the performance of supply chains as the question directly corresponds to research aim. The high frequency of "green" in relation to "strategies" and "supply" demonstrates that data extensively covers green practices and their application, with "strategies" being central to focus on environmental impact reduction strategies. While "performance" is not directly represented in this matrix, the co-occurrence of "strategies," "green," and "supply" implies discussions on how these strategies affect supply chain functions, inherently linking to

performance outcomes. The prominent intersection of "strategies" and "green" indicates significant discussions on explicit environmental impact reduction strategies, crucial for understanding how such strategies are pursued. Additionally, the high count for "supply" and "green" highlights that green initiatives are frequently discussed within the supply chain context, confirming that data provides specific insights into "green supply chain" practices. Finally, the notable intersection of "strategies" and "energy" suggests that energy-related strategies, such as energy efficiency and renewable energy adoption, are key components of environmental impact reduction efforts, offering a focused avenue for further exploration in research.

Fig. 8. Word Cloud Query for impact of environmental impact reduction strategies on supply chain performance

This is a word cloud of the frequency of words in text data, where the bigger a font size the more frequent a word appears (see Fig. 8). The most prominent terms include "environmental," which is the largest and most central term, directly reflecting the "environmental impact reduction" aspect of research objective, and "impact," which is very large and closely related to the "environmental impact" and the "impact of strategies." "Cost," highly prominent, suggests a strong economic dimension to environmental strategies, while "reduction" aligns directly with "environmental impact reduction." Terms such as "chain" and "supply" are also very large, emphasizing the central focus on "supply chain." "Sustainability," another central term, encompasses the broader context of environmental efforts, and "strategies" directly reflects the focus on the "strategies" aspect of objective. Other key terms like "waste," "performance," and "efficiency" are prominently featured, highlighting the importance of these concepts in the context of environmental impact reduction and operational performance. Moderately sized terms like "energy," "logistics," "operational," "reduce," "emissions," "carbon footprint," and "transportation" suggest a focus on energy consumption, transportation, and specific environmental impacts being addressed in the supply chain. Terms such as "materials," "product," "sourcing," "manufacturing," "recycling," "consumers," and "partnerships" indicate areas within the supply chain where environmental strategies are applied, as well as the role of demand-side factors and collaboration. The presence of terms like "risk," "regulatory," and "compliance" suggests that challenges, governance, and external pressures are important considerations. This word cloud strongly validates the relevance and depth of qualitative data for research objective: "To examine the impact of environmental impact reduction strategies on supply chain performance." The prominence of core terms such as "environmental," "impact," "reduction," "strategies," "supply," "chain," and "performance" indicates that these concepts are central to data. The emphasis on measurable outcomes, including "cost," "waste," "efficiency," "emissions," and "savings," indicates a focus not only on conceptual discussions but also on tangible impacts, which is crucial for examining the effectiveness of these strategies. As the data is presented, it gives a complete picture of the strategies at different levels and functions of supply chain, specifically the roles of companies, businesses, and collaboration and external forces in terms of pressures and risks that are posed by regulation.

4.4 Objective 4: To explore factors contributing to supply chain resilience within sustainable business models.

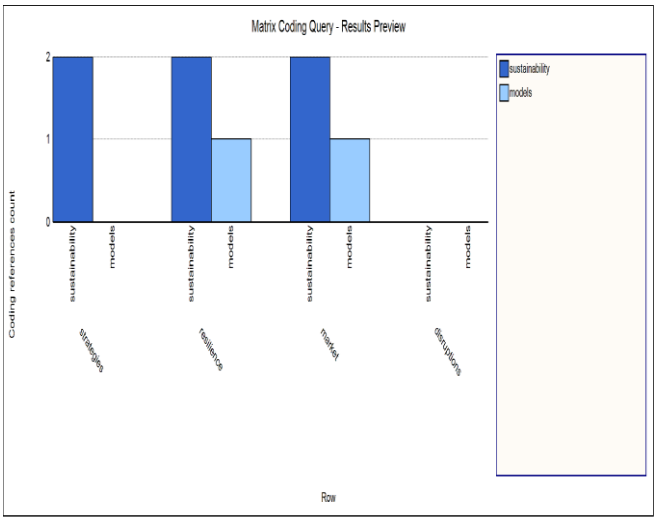

Fig. 9. Matrix Coding Query for factors contributing to supply chain resilience within sustainable business models

This NVivo matrix coding query (see Fig. 9) displays a bar chart showing the count of coding references for specified "Row" nodes against "Column" nodes, where the columns represent "sustainability" (dark blue bars) and "models" (light blue bars), and the rows represent "strategies," "resilience," "market," and "disruptions." The height of each bar indicates the number of coding references where a "Row" node intersects with a "Column" node. The visual representation reveals that the highest coding reference count occurs at the intersection of "resilience" and "sustainability," with a count of 2, followed by "strategies" and "sustainability" (also a count of 2) and "market" and "sustainability" (count of 2). The intersections of "resilience" and "models," and "market" and "models," both have a count of 1, while "strategies" coded with "models," and both "disruptions" coded with

"sustainability" and "models" have a count of 0, indicating no direct intersections in this query. This matrix query is very practical and relevant when it comes to the discussion of the factors that will make the supply chain resilient in the sustainable business models. The presence of "resilience," "sustainability," and "models" as key concepts in the matrix aligns with objective, confirming that data addresses discussions central to research. The strong connection between "resilience" and "sustainability," as evidenced by the highest coding reference count, suggests that data frequently explores how resilience is linked to sustainable practices, which is crucial for understanding how sustainable business models foster resilience. Similarly, the high count for "strategies" and "sustainability" indicates that various strategies aimed at sustainability are likely integral components of sustainable business models. The intersections of "market" with both "sustainability" and "models" suggest that market forces influence the design and effectiveness of sustainable business models in building resilience. The direct, though less frequent, link between "resilience" and "models" confirms that the data also addresses how models contribute to resilience, with the lower count suggesting that explicit connections between the two concepts may be less common. Lastly, the absence of direct links between "disruptions" and either "sustainability" or "models" may indicate that while disruptions are a key context for resilience, their direct mention in relation to these concepts is not prevalent in the current data segments, although resilience itself is inherently a response to disruptions.

Fig. 20. Word Cloud for impact of environmental impact reduction strategies on supply chain performance

This word-cloud (see Fig. 10) gives a visual display of the terms frequency in text data using font sizes to depict the frequency. Prominent terms include "supply" and "chain," both of which are central to data, with "supply" indicating its core role and "chain" typically co-occurring with "supply" to form "supply chain." "Sustainability" is extremely prominent, underscoring its central importance to research, while "resilience" is also very large, directly reflecting the key focus of objective. Other significant terms such as "practices," "environmental," "disruptions," and "changes" highlight the focus on actions, environmental dimensions, the need for resilience, and adaptability within supply chains. "Management" is substantial, indicating a strategic and operational focus, while "companies" and "businesses" suggest the involvement of organizational actors. Moderately sized terms like "models," "technologies," "market," and "strategies" directly link to sustainable business models and the role of technology in enhancing resilience. Terms such as "suppliers," "customers," "energy," "raw materials," and "data" indicate key stakeholders, resources, and the data-driven approaches central to building resilient supply chains. The presence of specific disruptions such as "pandemic" and "covid" suggests a focus on recent real-world challenges. Terms like "blockchain" and "circular economy" point to advanced technologies and sustainable practices as part of the solution. This word cloud is sufficient evidence that corpus will be very useful in meeting research goal to investigate the factors that promote supply chain resilience in sustainable business models. The frequent appearance of terms like "supply," "chain," "resilience," "sustainability," and "models" directly aligns with research goals, indicating that these core themes are well represented in data. The abundance of the words connected with disruptions, management, flexibility, and adaptation indicates that data discusses the drivers and specifics of resilience, as well as the process of using sustainable business models to increase resilience. The availability of the technological and data-driven terminologies further brings out the importance of innovation in enhancing supply chain resilience. Finally, the existence of the terms that refer to stakeholders and market dynamics implies the significance of organizational and external factors in developing resilient and sustainable supply chains.

4.5 Objective 5: To develop and assess metrics for evaluating sustainable business models in green supply chains using text analytics.

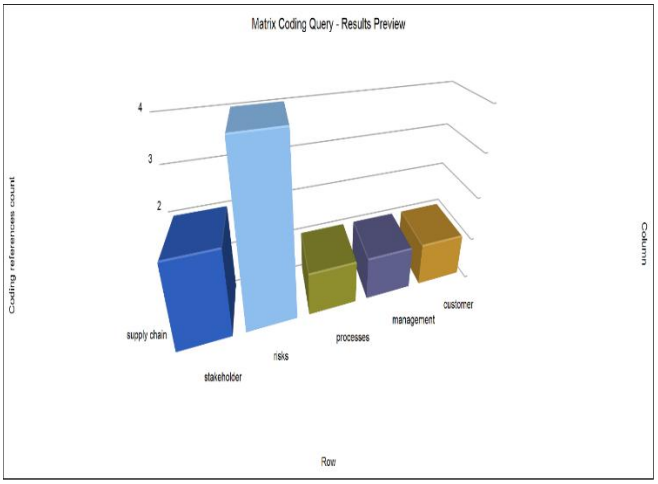

Fig. 31. Matrix Coding Query for evaluating sustainable business models in green supply chains using text analytics.

This NVivo matrix coding query (see Fig. 11) displays a 3D bar chart showing the coding reference count for specified "Row" nodes against "Column" nodes. Although

the columns are not clearly identified in the legend, they are identified by different colors in the bars and according to the common outputs of NVivo, these are probably the categories which are intersected. The rows include "supply chain," "risks," "processes," "management," and "customer," with an additional bar for "stakeholder" on the x-axis, suggesting it may be an implicit column or another dimension in the 3D display. The number of coding references is reflected by the height of every bar. The tallest bar, associated with "risks," shows a coding reference count exceeding 3.5, likely around 3.8, indicating a significant focus on risk management. "Supply chain" has a count of approximately 1.8, while "processes," "management," and "customer" show lower counts, ranging from 1 to 2, with "management" slightly above 1.5 and "customer" just below 1.5. "Stakeholder" is represented by the light blue bar next to "supply chain," and its high count suggests an intersection with "risks," highlighting its relevance to risk-related discussions. This matrix query is informative in the scope of devising and testing the metrics to measure the sustainable business models in green supply chains with text analytics. The prominence of "risks" emphasizes the importance of managing risks, particularly in sustainable business models within green supply chains, where mitigating risks such as environmental threats and disruptions is critical for performance and the development of appropriate metrics. The substantial coding for "supply chain" confirms that data aligns with research objective. The inclusion of "processes" and "management" indicates that the operational and strategic aspects of supply chains, where sustainable business models are implemented, are covered in data, thus offering areas for performance metric application. The presence of "customer" and "stakeholder" underscores the importance of external perspectives in evaluating supply chain performance and sustainability, with customer satisfaction and stakeholder engagement being key components of sustainable business metrics. Although "metrics" or "evaluation" are not directly labeled in this chart, the focus on "risks," "processes," and "management" within the supply chain context suggests the inherent need for measurement and assessment to gauge the effectiveness of sustainable business models and to identify areas for improvement.

Fig. 42. Word Cloud Query for evaluating sustainable business models in green supply chains using text analytics.

The visualization of this word cloud (see Fig. 12) represents the frequency of the terms in text data, where the larger font size presents the higher frequency. The most prominent terms include "sustainability," which is the most central and dominant term, directly aligning with "sustainable business models" and "green supply chains" in research objective, followed by "finance," indicating a strong focus on the financial aspects of sustainability. "Climate" is also highly prominent, suggesting a significant emphasis on climate-related issues, often central to environmental and green initiatives, while "adaptation" highlights discussions about climate change and resilience strategies. "Metrics," another large term, directly reflects the "metrics for evaluating" aspect of objective, with "resilience" representing the ability to withstand or recover from disruptions, a key feature of sustainable business models. The popularity of the term of analytics corresponds to interest in the topic of the use of text analytics to assess business models, and the popularity of the term investments means that there are conversations on the financial mechanisms that will help to sustain a given initiative. The presence of other conspicuous terms such as tools, performance, green, environmental, models and businesses lead to the identification of other areas of primary concern such as evaluation techniques, performance measurement and the situation of green supply chains. The external factors and issues covered by the sustainable models are also indicated by such terms as goals, objectives, risks, disruptions, stakeholder, and customer. This word cloud (word cloudO5.png) is a very interesting visualization of qualitative data and it also fits well with research objective, to develop and evaluate metrics to evaluate sustainable business models with green supply chains using text analytics. The fact that the terms, sustainability, metrics, models, and analytics, are most prominent, is a direct confirmation that data is extensively involved in such fundamental topics, which gives you an excellent basis to study. It can be emphasized that the terms concerning evaluation, which are commonly used, are: assess, evaluating, performance, and indicators that demonstrate the emphasis on creating assessment tools of sustainable business models. Moreover, the direct usage of the terms like green, environmental, and other words only supports the mentioned tendency of the specific attention to the sustainable supply chains. The fact that you added such words as climate, finance, and adaptation indicates that research is timely, particularly when it comes to climate finance and adaptation plans. Lastly, the existence of the words such as risks and disruptions indicates that data is concerned with the issues that the sustainable models are intended to solve, which provides an all-inclusive view on the creation of the metrics of assessing these models.

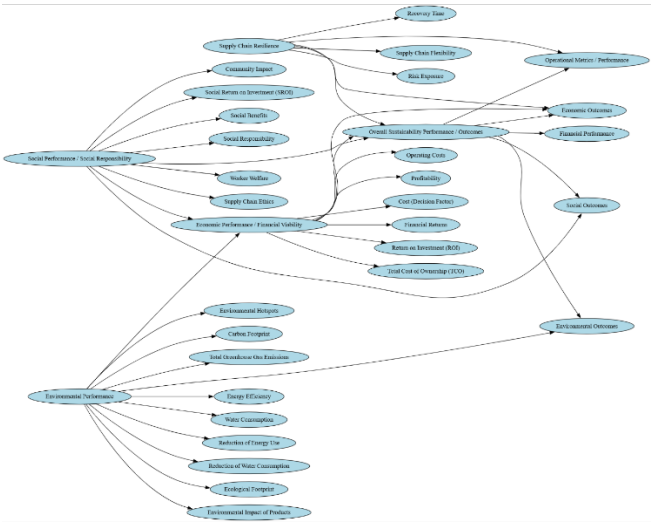

Fig. 53. Conceptual sustainable business models in green supply chains

In this diagram (see Fig.13), a conceptual model of the components and their relationship in a green supply chain is represented under three broad categories of performance namely Social, Economic and Environmental. The Social Performance / Social Responsibility node is a central node of social aspects, which connects to sub-components such as, Supply chain resilience, Community impact, Social Return on Investment (SROI), Worker welfare, and Supply chain ethics, which in turn impacts overall Sustainability performance / outcomes and directly reflects on social outcomes. The Economic Performance / Financial Viability node concerns the financial measures of "Operating Costs," "Profitability," "Return on Investment (ROI)," "Total Cost of Ownership (TCO)," which are part of the "Overall Sustainability Performance / Outcomes," and directly result in the "Economic Outcomes" and the "Financial Performance." The Environmental Performance node covers such ecological indicators as Carbon Footprint, Energy Efficiency, Water Consumption and Ecological Footprint, and contributes to Overall Sustainability Performance / Outcomes and has an impact on Environmental Outcomes. The arrows in the model show the directional impact or contribution of sub-components to larger categories or results whereby the Operational Metrics / Performance is influenced by the Supply Chain Flexibility and Risk Exposure which connects the operational performance to the financial performance. In terms of generating and quantifying the metrics to assess sustainable business models in green supply chains through the assistance of text analytics, this diagram can be very useful and provides a firm conceptualization. The fact that the model covers the three pillars of sustainability well, i.e. social, economic, and environmental, deals directly with the aspect of sustainable business models, which provides a clear description of what such models are. The diagram specifies the possible evaluation metrics such as environmental metrics (Carbon Footprint, Water Consumption), economic metrics (Operating Costs, ROI), social metrics (SROI, Worker Welfare), and directly reflects the goal of the development and evaluation of the metrics. The model's grounding in the context of green supply chains is underscored by its emphasis on environmental performance metrics. Furthermore, the hierarchical structure and interconnections highlight the relationships between various factors, providing insights into what to evaluate and how metrics are interrelated, such as the connection between "Supply Chain Resilience" and "Social Performance." Lastly, this model serves as a great basis of text analytics since the particular terms and concepts used present a firm ground to examine the frequency, co-occurrence, and relationships of these factors in the text data, which allows making a full evaluation of the emphasis and content concerning these measures.

The comparison of the different approaches to text analysis with the research showed a sophisticated picture of the correspondence of each method with the definite goals. Thematic analysis was useful at describing general trends and conceptual themes in SBM design and environmental approaches but was not quantitatively rigorous to develop metrics. The content analysis became a good candidate in quantifying the large data and coming up with standardized measures and thus it can be very beneficial in assessing the environmental strategies and performance indicators. Sentiment analysis provided information on stakeholder perception and regulatory pressure, but it could not be used much in the development of actionable measures or investigation of technical aspects. Although the network analysis is complicated, it was unique in terms of mapping the interdependencies and the assessment of resilience factors in the supply chain.

The Natural Language Processing (NLP) method of Text Mining eventually emerged as the most reliable and versatile one that can provide enhanced possibilities to process large amounts of unstructured data, calculate quantifiable values, and draw the trends and research gaps. Such an approach was most consistent with all the five research objectives, particularly, regarding the development of standardized metrics and the assessment of the role of advanced technologies. Although Content Analysis and Network Analysis were judged as being of high relevance to certain goals, namely, development of metrics and supply chain resiliency, Text Mining with NLP was suggested to be the most useful source as it is applicable to a wide range of goals. It was advised to combine NLP with secondary techniques such as Content and Network Analysis to use their complementary abilities in the study of sustainable business models in green supply chains in a more integrated fashion.

5. Conclusion

The objective of the research was to discuss the contribution of sustainable business models (SBMs) to green supply chain performance. The research aimed at revealing the impact of sustainability goals integration into business models on the level of operational efficiency, environmental performance, and the overall performance of the supply chain in terms of resilience. Based on the extensive review of different frameworks, the study highlights the need to embrace green practices, innovative technologies, and partnerships in the achievement of sustainable supply chains. The main

findings on the managerial, research, societal, and future implications of this study can be seen below.

5.1 Managerial Implications

Managers ought to understand that the implementation of SBMs may be environmentally and economically beneficial as long-term results in efficiency and cost-effectiveness of operations. Implementing sustainability, the companies will be able not only to decrease the ecological footprints, but also to improve the competitive standing. As an example, the use of such advanced technologies as blockchain, AI, and IoT can make the supply chain more transparent, allow optimizing resources and cutting operational costs. Also, it is important to promote cooperation between the stakeholders such as suppliers, regulators, and customers, to break the barrier towards sustainability and to ensure alignment with sustainability objectives. The problems of high initial investments and integration of technology into the management process should also be considered by the managers, and a strategic planning should be conducted to determine the short-term costs and the long-term benefits.

5.2 Research Implications

The study will add to the already existing literature on the sustainable business models and green supply chains by providing empirical evidence on the connection between sustainability integration and supply chain performance. The results give us much insight on the real-life issues that businesses must encounter when they are trying to align their operations to meet environmental and social sustainability objectives. The ways in which SBMs, including, circular economy models or sustainable procurement practices, can be operationalized within various industries may be examined in future research, as well. Also, there should be research on standardized measures and evaluation instruments of measuring the SBM success that would enable better benchmarking and tracking of performance.

5.3 Societal Implications

At the society level, the results stress the importance of businesses in enhancing sustainability endeavours. Greening of the supply chain will not only help companies protect the environment, but it will also help to ensure the stability of the global economies. When the businesses align their business strategies with the environmental intentions, they will be able to cut down on their environmental impact, thereby solving some of the burning issues, including resource depletion, pollution, and climate change. Nevertheless, the research also points out to the necessity of further cooperation between the public and the private sector to eliminate regulatory and practical obstacles to sustainability.

5.4 Future Directions

Professional studies must focus on the process of SBMs integration with global disturbances like the COVID-19 pandemic. Logical studies of how companies modify their green supply chains during times of crisis would be of great importance in terms of resilience and flexibility. Moreover, the current development of new technologies will also be useful to research and study their contribution to the enhancement of sustainability indicators and the optimization of green supply chains. Studies of the social aspects of SBMs, including labor rights, community wellbeing, and stakeholder participation, might as well present a more comprehensive picture of sustainability. Finally, further development of the tools to measure the effect of sustainable practices on the business performance as well as environmental performance will be necessary to direct businesses towards more efficient application of the green supply chain strategies.

Despite the difficulties, implementing sustainable business models provides an optimistic direction of enhancing the performance of the green supply chain, which would result in the benefits of businesses, society, and environment. By means of further research and innovation, companies can open new possibilities of sustainability-led growth and resilience**.**

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