

SUSTAINABILITY IN SUPPLY CHAINS: STRATEGIES AND PRACTICES FOR A GREENER FUTURE

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ABSTRACT

Purpose – The purpose of this study is to investigate the critical importance of integrating sustainability practices into supply chain management. It aims to explore strategies and best practices that businesses can adopt to mitigate environmental challenges, reduce greenhouse gas emissions, and transition towards greener supply chains.

Implications – The integration of sustainability into supply chain management has far-reaching implications for businesses, the environment, and society. By adopting sustainable practices, organizations can enhance their brand reputation, increase customer loyalty, achieve cost savings, improve risk management, foster innovation, and gain a competitive advantage. Additionally, the adoption of green supply chain practices contributes to environmental conservation, resource efficiency, and the mitigation of climate change impacts.

Originality/Value – This study offers a comprehensive analysis of sustainable supply chain practices, with a particular focus on Thailand's manufacturing sector. It provides valuable insights into the challenges and opportunities associated with implementing sustainability strategies across various industries. The research highlights best practices, case studies, and recommendations tailored to the Thai context, enabling businesses to navigate the transition towards greener supply chains effectively. Furthermore, the study emphasizes the significance of Thailand's sustainability efforts in influencing global standards and positioning the nation as a leader in responsible manufacturing practices.

Keywords: Sustainability, Supply chains, Green practices

Paper Type: Academic Article

INTRODUCTION

Supply chains have evolved significantly due to digitalization, e-commerce growth, and the emergence of new business opportunities in base-of-the-pyramid (BoP) markets. The impact of e-commerce on supply chains has led to operational challenges, emphasizing the need for firms to manage growth effectively and develop sustainable practices (Al Mashalah et al., 2022). Additionally, the BoP markets present unique challenges, requiring firms to rethink traditional business models and develop innovative supply chain solutions to cater to the needs of these markets (Khalid et al., 2022). Supply chain resilience is crucial in coping with unexpected turbulence, with digital tools playing a key role in enhancing visibility and collaboration within supply chains (Zouari et al., 2021). Furthermore, the green food supply chain is gaining popularity, with consumers increasingly concerned about environmentally friendly practices in food production and distribution (Khalid et al., 2022). The use of technology and digital transformation in supply chain management has the potential to address sustainability challenges and optimize efficiency. However, there is still a need for more focused efforts to integrate these technological advancements into a comprehensive understanding of sustainability in supply chains. With the rise in global consumption and the consequent intensive

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demand for global resources, the attention of scholars and practitioners towards greener supply chains has grown over the years (Giuffrida & Mangiaracina, 2020). Businesses are gradually raising awareness of the impact of integrating supply chains and environmental management systems to create a sustainable business strategy.

Sustainability holds paramount importance in today's business landscape due to the increasing volatility and uncertainty caused by various crises like the COVID-19 pandemic, energy crisis, global supply chain issues, and conflicts (Markovic et al., 2023). Organizations are expected to positively impact society, reduce environmental footprints, and build authentic brands to stay competitive (Sassanelli & Terzi, 2023). Therefore, implementing sustainable practices in supply chains not only benefits businesses but also the environment (Giuffrida & Mangiaracina, 2020). The concept of corporate sustainability is crucial for organizations worldwide, with a focus on economic, environmental, and social goals that aim to create long-term value for all stakeholders involved (Politis & Grigoroudis, 2022). Integrating sustainability into core business functions is a significant challenge faced by modern enterprises, emphasizing the necessity of aligning brand values with sustainability efforts to build strong identities and reputations and gain a competitive advantage (Ajmal et al., 2018). The interconnectedness of people, businesses, and societies further underscores the need for sustainable practices to address the challenges faced by organizations in both public and private sectors and foster greater collaboration among supply chain partners to achieve shared sustainability goals (Visvizi, 2022).

In this context, the adoption of green supply chain management practices becomes crucial (Zailani et al., 2012). Green supply chain management refers to the integration of environmental considerations into all aspects of supply chain operations, including product design, sourcing, manufacturing, transportation, and disposal. This approach aims to minimize the negative environmental impacts associated with supply chain activities while maximizing efficiency and value creation. By implementing green supply chain management practices, businesses can reduce their carbon footprint, minimize waste generation, conserve natural resources, and promote the use of sustainable materials, all of which contribute to building a more sustainable business strategy (Sarwar et al., 2021). Furthermore, green supply chain management is aligned with the growing consumer preference for environmentally friendly goods and services (Zailani et al., 2012). Therefore, organizations that embrace green supply chain management gain a competitive advantage by meeting customer demands, reducing costs, and enhancing their reputation as socially and environmentally responsible entities (Sarwar et al., 2021).

This article examines how Thailand's manufacturing sector can leverage technology for sustainable supply chain management (SCM). A mixed-methods approach employing an extensive literature review alongside qualitative and quantitative analysis techniques explores challenges and opportunities in this specific context.

The literature review formed the foundation, utilizing databases like ScienceDirect and keywords like "sustainable supply chain" and "Thailand manufacturing" to identify relevant research (147 sources reviewed). This comprehensive approach provides a strong foundation for investigating sustainable SCM practices within Thailand's manufacturing sector.

ENVIRONMENTAL CHALLENGES IN SUPPLY CHAINS

Major environmental concerns associated with traditional supply chains include carbon emissions, resource depletion, and pollution (Gonzalez et al., 2022). Carbon emissions are a significant issue, leading to environmental degradation and climate change (Jæger et al., 2021). These emissions are a result of transportation, energy consumption, and manufacturing processes throughout the supply chain. To address this challenge, supply chain managers can focus on implementing sustainable transportation methods, adopting energy-efficient technologies, and promoting renewable energy sources. Additionally, traditional supply chains often contribute to resource depletion through inefficient practices and lack of sustainability measures (Homayouni et al., 2023). By adopting green supply chain practices, organizations can mitigate these challenges by implementing strategies such as waste reduction, recycling programs, and responsible sourcing of materials (Sarwar et al., 2021). Pollution is another critical concern, with supply chains in various industries exhibiting environmentally destructive

behaviors that harm ecosystems and communities (Sarkis et al., 2021). To combat pollution, organizations can prioritize the use of environmentally friendly materials and production methods, implement waste management systems, and enforce strict environmental regulations throughout their supply chain (Sarwar et al., 2021). Furthermore, the integration of sustainability into supply chain management practices requires collaboration and cooperation among various stakeholders. These issues highlight the urgent need for organizations to transition towards green supply chain practices to mitigate the negative environmental impacts of traditional supply chains and work towards a more sustainable future (Jæger et al., 2021). Incorporating sustainable practices in supply chain management can lead to reduced environmental impact, improved resource efficiency, and greater resilience in the face of environmental challenges (Sarwar et al., 2021). By addressing these concerns through sustainable logistics models, environmental regulations, and investments in pro-environment approaches, organizations can work towards greener and more sustainable supply chains.

The environmental impact of supply chains can be quantified through various methods and examples provided in the literature. Studies highlight that green supply chains lead to improvements in resource conservation, energy reduction, environmental communication management, and pollution control, among other benefits. Environmental impacts in food supply chains are mainly attributed to land use change and agricultural production, with livestock having a higher footprint than plant based (Sutawidjaya et al., 2021). Additionally, emissions from transportation in supply chains contribute to air pollution and greenhouse gas emissions. To address these challenges, organizations can implement strategies such as optimizing transportation routes, using alternative fuel vehicles, and adopting lean manufacturing techniques to minimize waste and energy consumption. Analyzing the environmental evaluation of a swimming goggles distribution revealed that materials and manufacturing phases have the highest impacts, emphasizing the importance of quantifying and rationalizing environmental impacts in complex systems such as supply chains (Zailani et al., 2012). Additionally, the implementation of IoT technologies in food supply chains can help reduce environmental impacts by preventing food waste generation and associated impacts, such as greenhouse gas emissions from food spoilage and transportation.

Overall, the integration of green supply chain practices is crucial for organizations to address environmental concerns and promote sustainability. In order to achieve a greener future, organizations must recognize the importance of integrating sustainable practices into their supply chain management (Zailani et al., 2012). By doing so, they can identify and address operational bottlenecks that contribute to environmental challenges, such as poor inventory management, inefficient tracking and tracing, and the presence of counterfeit or sub-standard products. These practices, which include green purchasing, green packaging, green manufacturing, green design, and green marketing, can contribute to improved environmental performance and a reduced carbon footprint.

STRATEGIES FOR SUSTAINABLE SUPPLY CHAINS

In today's competitive landscape, organizations are increasingly recognizing the strategic importance of sustainable supply chain management (SSCM). This entails integrating environmental, social, and economic considerations into all aspects of the supply chain, from sourcing to end-of-life product management. By implementing robust SSCM strategies, companies can enhance operational efficiency, mitigate risk, and gain a competitive advantage.

Key Strategies for a Sustainable Supply Chain:

1. Sustainable Procurement: A Strategic Imperative for Resilient Supply Chains

In today's globalized marketplace, organizations are increasingly recognizing the strategic importance of sustainable procurement practices. This approach transcends traditional cost-centric purchasing by integrating environmental, social, and governance (ESG) considerations throughout the sourcing process. Implementing a robust sustainable procurement strategy fosters a more resilient and responsible supply chain, yielding a multitude of benefits for organizations.

1.1 Benefit of Sustainable Procurement:

1) Environmental Impact Reduction: By partnering with suppliers committed to sustainable practices (e.g., energy efficiency, waste reduction), companies can significantly contribute to minimizing their environmental footprint throughout the supply chain (Etse et al., 2023).

2) Enhanced Social Responsibility: Sustainable procurement empowers organizations to support suppliers who uphold ethical labor standards and responsible sourcing of materials, promoting positive social impacts within their supply networks (Hiep et al., 2021).

3) Risk Mitigation: A comprehensive assessment of a supplier's ESG performance helps identify potential risks associated with environmental regulations, social unrest, or resource scarcity within their operations, enabling proactive risk management strategies (Bratt et al., 2021).

4) Cost Optimization: Sustainable practices often lead to operational efficiencies for both you and your suppliers. This could involve aspects like reduced energy consumption, minimized waste generation, or the use of recycled materials, all contributing to long-term cost optimization (Bratt et al., 2021).

1.2 Implementing a Sustainable Procurement Strategy:

1) Supplier Evaluation with a Sustainability Focus

Traditional procurement practices often prioritize cost reduction as the sole selection criterion. To effectively integrate sustainability principles, organizations must adopt a more comprehensive approach for supplier evaluation. This involves incorporating Environmental, Social, and Governance (ESG) factors alongside traditional cost and quality metrics. This might involve evaluating a supplier's:

- Energy and resource efficiency initiatives
- Waste management protocols and recycling programs
- Labor standards and commitment to ethical sourcing
- Certifications related to sustainability (e.g., Fair Trade, Forest Stewardship

Council)

2) Collaborative Partnerships: Building strong and collaborative relationships with suppliers is essential for achieving long-term success in sustainable procurement. Effective collaboration fosters continuous improvement in sustainability practices throughout the supply chain (Hahn et al., 2018).

- Open Communication and Collaborative Engagement: Establish open communication channels with your suppliers. Engage in collaborative discussions to identify opportunities for ongoing improvement in environmental and social responsibility.

- Knowledge Sharing Through Supplier Engagement: Consider organizing workshops or training sessions to equip your suppliers with the necessary knowledge and tools to enhance their own ESG performance.

3) Transparency & Communication: Be transparent about your own sustainability goals and expectations for your suppliers. Regularly communicate your progress in sustainable procurement practices and encourage your suppliers to do the same (Hahn et al., 2018).

- Clear Communication of Sustainability Expectations: Clearly communicate your organization's sustainability goals and the ESG criteria used during supplier evaluation.

- Tracking Progress and Transparent Reporting: Regularly monitor progress towards your established sustainability goals. Communicate achievements and challenges openly with stakeholders, including suppliers, customers, and investors.

- Regular Review and Adaptation: As your business and the sustainability landscape evolve, it is essential to periodically review your goals and evaluation criteria. This ensures they remain relevant and impactful in achieving your long-term sustainability objectives.

2. Sustainable Product Design & Lifecycle Management (SPDLCM)

Sustainable Product Design & Lifecycle Management (SPDLCM) is a strategic framework employed by leading organizations to achieve environmental and social responsibility throughout a product's entire lifespan. This holistic approach transcends traditional product design by meticulously considering a product's impact – from raw material extraction and

manufacturing to use, end-of-life management, and potential for reuse or remanufacture. By integrating SPDLCM principles, organizations can significantly contribute to a more circular economy, minimizing resource depletion, waste generation, and environmental footprint.

2.1 Core Tenets of SPDLCM:

1) Design for Disassembly & Remanufacture: SPDLCM prioritizes designing products for ease of disassembly. This allows for efficient component separation, facilitating reuse or remanufacture at the end of a product's useful life (Favi et al., 2019). This approach extends product lifespans, reduces reliance on virgin materials, and minimizes landfill waste.

2) Material Selection with Sustainability in Mind: Material selection is a critical aspect of SPDLCM. Opting for recycled or readily recyclable materials whenever possible minimizes environmental burdens associated with virgin material extraction, processing, and transportation throughout the supply chain (Vezzoli, 2014).

3) Energy Efficiency Optimization: SPDLCM emphasizes designing products that minimize energy consumption during their use phase. This can involve optimizing product functionalities, employing energy-efficient components, and providing clear user instructions for energy-saving operation (Favi et al., 2019).

4) Life Cycle Assessment (LCA) Integration: SPDLCM leverages Life Cycle Assessment (LCA) tools to comprehensively evaluate the environmental impact of a product across all stages of its lifecycle (Ingrao et al., 2021). LCA insights inform design decisions that promote environmental sustainability by identifying areas for improvement in resource utilization and waste reduction.

5) End-of-Life Management Strategies: Developing responsible end-of-life management strategies is paramount in SPDLCM. Take-back programs, robust recycling initiatives, and safe disposal options significantly minimize landfilling and promote the recovery of valuable resources (Favi et al., 2019).

2.2 Benefits of Implementing SPDLCM:

1) Reduced Environmental Impact: By minimizing resource consumption, energy use, and waste generation, SPDLCM contributes significantly to achieving environmental sustainability goals and mitigating climate change.

2) Enhanced Brand Reputation: Consumers are increasingly drawn to brands demonstrating a commitment to sustainability. Implementing SPDLCM practices fosters a positive brand image and attracts environmentally conscious customers.

3) Cost Optimization: Resource and material efficiency strategies inherent in SPDLCM can lead to cost savings throughout a product's lifecycle, from material sourcing to manufacturing and potentially even end-of-life management processes.

4) Innovation Opportunities: SPDLCM fosters innovation in product design, materials science, and the development of sustainable end-of-life management solutions.

2.3 Effective Implementation of SPDLCM:

1) Cross-Functional Collaboration: Effectively implementing SPDLCM requires fostering collaboration between design, engineering, manufacturing, and marketing teams. Integrating sustainability considerations into all stages of product development is crucial.

2) Strategic Supplier Engagement: Partnering with suppliers who share your commitment to sustainability is key. Aligning with suppliers who prioritize environmentally responsible practices and utilize sustainable materials strengthens your overall sustainability efforts.

3) Consumer Education & Engagement: Educating consumers about a product's sustainable features and proper end-of-life disposal practices empowers them to make informed choices and participate in a more circular economy.

3. Sustainable Operations & Logistics

Optimize transportation efficiency by consolidating shipments, employing fuel-efficient vehicles, and exploring alternative transportation methods like rail or sea freight, where feasible (Grant et al., 2017). Additionally, implement strategies to minimize waste generation throughout the supply chain. This could involve optimizing production processes, utilizing recyclable packaging materials, and exploring waste-to-energy solutions (Rabbani et al., 2018).

3.1 Transportation Optimization: Optimizing transportation networks and logistics planning is fundamental to SOL. Techniques such as consolidating shipments, adopting fuel-efficient or alternative fuel vehicles (e.g., electric, hybrid), and implementing route planning software can significantly reduce carbon emissions and overall fuel consumption within the supply chain (Grant et al., 2017). Here are some core strategies for transportation optimization:

1) **Route Optimization:** Utilize advanced routing software to plan the most efficient delivery routes. Consider factors such as distance, traffic patterns, delivery windows, and vehicle capacities to minimize fuel consumption and emissions while maximizing delivery speed (Rabbani et al., 2018).

2) **Consolidation and Collaboration:** Consolidate shipments whenever possible to reduce the number of vehicles on the road. Collaborate with other businesses or partners to share transportation resources and optimize delivery routes collectively, reducing empty miles and lowering carbon footprints (Rabbani et al., 2018).

3) **Mode Shifting:** Evaluate different transportation modes (e.g., truck, rail, ocean freight) and choose the most environmentally friendly and cost-effective options for each shipment. Where feasible, shift from road to rail or water transport for long-distance shipments to reduce greenhouse gas emissions (Schiller & Kenworthy, 2017).

4) **Fleet Optimization:** Invest in fuel-efficient vehicles and maintain them regularly to ensure optimal performance. Consider alternative fuel options such as electric, hybrid, or natural gas vehicles to reduce reliance on fossil fuels and minimize emissions (Rabbani et al., 2018).

5) **Load Optimization:** Maximize the payload of each vehicle to reduce the number of trips required for transportation. Use load planning software to efficiently utilize cargo space and minimize wasted capacity, thereby reducing the overall environmental impact per shipment (Schiller & Kenworthy, 2017).

6) **Last-Mile Delivery Solutions:** Implement innovative last-mile delivery solutions such as bicycle couriers, electric vans, or drone delivery for urban areas to reduce congestion and emissions associated with traditional delivery methods (Schiller & Kenworthy, 2017).

7) **Real-Time Monitoring and Tracking:** Utilize IoT (Internet of Things) technology and GPS tracking systems to monitor vehicle performance, track shipments in real-time, and identify opportunities for route optimization and efficiency improvements (Schiller & Kenworthy, 2017).

8) **Reverse Logistics Optimization:** Develop efficient processes for managing returns and reverse logistics to minimize transportation-related waste and emissions. Implement strategies such as product refurbishment, recycling, or resale to reduce the environmental impact of returned goods (Bratt et al., 2021).

9) **Supplier Collaboration:** Collaborate closely with suppliers to optimize transportation processes across the entire supply chain. Implement just-in-time inventory management practices to minimize storage and transportation costs while ensuring timely deliveries (Bratt et al., 2021).

3.2 Warehouse Optimization: Warehousing efficiency plays a critical role in achieving sustainability goals. Strategies such as implementing energy-efficient lighting and heating/cooling systems, maximizing space utilization through efficient layout design, and employing automation for repetitive tasks can significantly minimize energy consumption and the overall environmental footprint of warehousing operations (Wahab et al., 2021).

Here are some core strategies for warehouse optimization with a focus on sustainability:

1) **Inventory Management:** Implement lean inventory management practices to minimize excess stock and reduce storage space requirements. By accurately forecasting demand and maintaining optimal inventory levels, warehouses can minimize waste and energy consumption associated with storage and handling (Torabizadeh et al., 2020; Wahab et al., 2021).

2) **Energy Efficiency:** Invest in energy-efficient lighting, heating, ventilation, and cooling systems within the warehouse. Implement motion sensors and timers to automatically adjust lighting and HVAC systems based on occupancy and usage patterns, thereby reducing energy waste (Torabizadeh et al., 2020).

3) Green Building Design: Design or retrofit warehouses with sustainable building materials and practices to minimize environmental impact. Incorporate features such as natural lighting, rainwater harvesting systems, and solar panels to reduce energy consumption and reliance on non-renewable resources (Wahab et al., 2021).

4) Optimized Layout: Design warehouse layouts to minimize travel distances and optimize material flow. Group frequently picked items together and arrange storage locations based on demand patterns to reduce picking and transportation times, thereby improving overall efficiency and reducing emissions (Torabizadeh et al., 2020; Wahab et al., 2021).

5) Automation and Robotics: Implement warehouse automation technologies such as conveyor systems, robotic picking, and automated guided vehicles (AGVs) to improve efficiency and reduce labor and energy costs. Automation can also optimize space utilization and minimize the need for additional warehouse expansion (Torabizadeh et al., 2020; Wahab et al., 2021).

6) Packaging Optimization: Optimize packaging materials and design to minimize waste and maximize space utilization during storage and transportation. Use recyclable or biodegradable packaging materials whenever possible and implement packaging reusability programs to reduce environmental impact (Wahab et al., 2021).

7) Reverse Logistics Handling: Develop efficient processes for handling returns and reverse logistics within the warehouse. Implement systems for sorting, refurbishing, recycling, or disposing of returned products in an environmentally responsible manner to minimize waste and maximize resource recovery (Wahab et al., 2021).

8) Supplier Collaboration: Collaborate closely with suppliers to optimize inbound logistics and streamline receiving processes. Implement vendor-managed inventory (VMI) or just-in-time (JIT) delivery practices to reduce inventory holding costs and minimize transportation emissions associated with frequent deliveries (Torabizadeh et al., 2020; Wahab et al., 2021).

3.3 Sustainable Packaging: Rethinking packaging strategies is a key component of SOL. Utilizing recycled content in packaging materials, opting for minimal or biodegradable packaging solutions, and implementing product return programs can minimize waste generation and resource depletion throughout the supply chain (Ibrahim et al., 2022).

Here are some core strategies for implementing sustainable packaging practices:

1) Material Selection: Choose packaging materials that are renewable, recyclable, or biodegradable. Optimize for materials such as paperboard, corrugated cardboard, recycled paper, bioplastics, or compostable materials to reduce environmental impact (Ibrahim et al., 2022; Siracusa & Rosa, 2018).

2) Right-Sizing: Optimize packaging sizes to minimize material usage and maximize space efficiency during storage and transportation. Use packaging design software or consulting services to design packaging that fits products snugly, reducing the need for excess filler material (Siracusa & Rosa, 2018).

3) Reusable Packaging: Implement reusable packaging solutions such as pallets, containers, and totes to minimize waste and reduce the environmental impact of single-use packaging. Develop reverse logistics processes to recover and refurbish reusable packaging items for multiple cycles of use (Kozik, 2020).

4) Minimalist Design: Design packaging with simplicity and minimalism in mind to reduce material usage and waste. Avoid unnecessary embellishments, excessive layers, and non-functional elements that contribute to environmental harm without adding value to the product (Kozik, 2020).

5) Recycled Content: Use packaging materials with high levels of recycled content to reduce demand for virgin materials and support the recycling industry. Look for packaging suppliers that offer products certified by organizations such as the Forest Stewardship Council (FSC) or the Sustainable Forestry Initiative (SFI) (Ibrahim et al., 2022; Kozik, 2020; Siracusa & Rosa, 2018).

6) Biodegradable and Compostable Options: Explore biodegradable and compostable packaging options for products that require disposal after use. Ensure that

biodegradable and compostable packaging materials meet relevant industry standards and certifications to guarantee their environmental benefits (Siracusa & Rosa, 2018).

7) Packaging Innovation: Invest in research and development to explore innovative packaging solutions that reduce environmental impact while maintaining product integrity and functionality. Consider alternatives such as edible packaging, mushroom-based packaging, or seaweed-based packaging for specific applications (Ibrahim et al., 2022)

8) Supplier Collaboration: Collaborate closely with packaging suppliers to align sustainability goals and drive continuous improvement in packaging practices. Request sustainability information from suppliers and prioritize partnerships with vendors committed to environmental stewardship (Ibrahim et al., 2022).

9) Consumer Education: Educate consumers about the importance of sustainable packaging and provide guidance on proper disposal methods to promote recycling, composting, or reuse. Use packaging labels, marketing materials, and online platforms to communicate sustainability efforts and encourage responsible consumer behavior (Kozik, 2020).

10) Life Cycle Assessment: Conduct life cycle assessments (LCAs) to evaluate the environmental impact of packaging materials and processes across the entire product life cycle. Use LCA data to identify areas for improvement and guide decision-making towards more sustainable packaging options (Ibrahim et al., 2022; Kozik, 2020; Siracusa & Rosa, 2018).

3.4 Waste Reduction & Management: Developing comprehensive waste reduction and management strategies is essential for SOL. This could involve implementing source reduction practices in production processes, establishing robust recycling programs for various waste streams, and exploring waste-to-energy solutions (where feasible) to divert waste from landfills (Elsaid & Aghezzaf, 2015). Here are some core strategies for effectively reducing and managing waste in business operations:

1) Source Reduction: Minimize waste generation at the source by optimizing processes, reducing excess packaging, and eliminating unnecessary materials. Design products with durability and reusability in mind to extend their lifecycle and reduce disposal rates (Cucchiella et al., 2017).

2) Recycling Programs: Implement comprehensive recycling programs to capture and recycle materials such as paper, cardboard, plastics, glass, and metals. Provide easily accessible recycling bins throughout facilities and educate employees on proper recycling practices to maximize participation and diversion rates (Cucchiella et al., 2017).

3) Composting: Implement composting programs to divert organic waste from landfills and convert it into nutrient-rich compost for use in landscaping or agricultural applications. Collect food scraps, yard waste, and other organic materials separately and compost them on-site or through third-party composting facilities (Awasthi et al., 2021).

4) Waste Audits: Conduct regular waste audits to identify sources of waste generation, quantify waste streams, and pinpoint opportunities for waste reduction and diversion. Analyze audit findings to prioritize improvement initiatives and set measurable waste reduction targets (Elsaid & Aghezzaf, 2015).

5) Supplier Engagement: Collaborate with suppliers to minimize packaging waste, optimize packaging sizes, and source materials with recycled content. Encourage suppliers to adopt sustainable practices and provide incentives for waste reduction and recycling efforts throughout the supply chain (Awasthi et al., 2021; Cucchiella et al., 2017; Elsaid & Aghezzaf, 2015).

6) Product Redesign: Redesign products and packaging to minimize waste generation and facilitate end-of-life recovery. Use design principles such as lightweighting, material substitution, and modular design to optimize product recyclability, reusability, and disassembly for recycling or remanufacturing (Awasthi et al., 2021; Cucchiella et al., 2017; Elsaid & Aghezzaf, 2015).

7) Closed-Loop Systems: Implement closed-loop systems to recover and reuse materials within the production process. Collect and recycle manufacturing by-products, scrap materials, and obsolete products to minimize waste and conserve resources, reducing the need for virgin materials (Awasthi et al., 2021; Cucchiella et al., 2017).

8) **Regulatory Compliance:** Stay informed about waste management regulations and compliance requirements at the local, regional, and national levels. Ensure compliance with waste disposal regulations, hazardous waste management requirements, and reporting obligations to avoid fines and penalties (Elsaid & Aghezzaf, 2015).

3.5 Renewable Energy Integration: Investing in renewable energy sources such as solar or wind power to supplement or replace conventional electricity in facilities can substantially reduce greenhouse gas emissions and dependence on fossil fuels (Al-Shetwi, 2022). Here are core strategies for effectively incorporating renewable energy:

1) **On-Site Renewable Energy Generation:** Install renewable energy systems such as solar panels, wind turbines, or biomass generators on-site to generate clean electricity. Evaluate the site's renewable energy potential and invest in appropriate technologies to offset energy consumption from conventional sources (Al-Shetwi, 2022).

2) **Power Purchase Agreements (PPAs):** Enter into PPAs with renewable energy developers to procure electricity from off-site renewable energy projects. PPAs allow businesses to access renewable energy without the upfront costs of installation and maintenance, while supporting the growth of renewable energy infrastructure (Al-Shetwi, 2022).

3) **Energy Storage Systems:** Deploy energy storage systems such as batteries or pumped hydro storage to store excess renewable energy for later use. Storage systems enhance the reliability and stability of renewable energy sources, enabling better integration into operations and logistics (Al-Shetwi, 2022).

4) **Energy Efficiency Improvements:** Prioritize energy efficiency measures to reduce overall energy demand and optimize the performance of renewable energy systems. Implement lighting upgrades, HVAC system improvements, and equipment retrofits to minimize energy consumption and maximize renewable energy utilization (Al-Shetwi, 2022).

5) **Smart Grid Integration:** Integrate renewable energy systems with smart grid technologies to optimize energy distribution and consumption. Utilize demand response programs, energy management systems, and grid-connected inverters to balance supply and demand dynamically, leveraging renewable energy resources effectively (Le Guen et al., 2018).

6) **Fleet Electrification:** Transition fleet vehicles to electric or hybrid models powered by renewable energy sources. Invest in electric vehicle (EV) charging infrastructure and fleet management software to optimize charging schedules and routes, reducing fuel costs and emissions associated with transportation operations (Al-Shetwi, 2022).

7) **Green Building Design:** Design or retrofit facilities to meet green building standards and certifications, incorporating renewable energy generation, energy-efficient HVAC systems, and passive design strategies. Construct buildings with high-performance insulation, efficient lighting, and daylighting to minimize energy demand and reliance on non-renewable sources (Le Guen et al., 2018).

8) **Carbon Offsetting:** Offset remaining carbon emissions from operations and logistics through investments in carbon offset projects such as reforestation, renewable energy development, or methane capture. Partner with reputable offset providers and transparently communicate offsetting efforts to stakeholders (Al-Shetwi, 2022).

4. Collaboration & Transparency

Foster strong relationships with suppliers by collaborating on identifying and implementing sustainability improvements throughout the supply chain. Open communication and knowledge sharing are essential for achieving shared goals and fostering a culture of continuous improvement (Mason, 2020). Additionally, prioritize transparency by publicly disclosing sustainability efforts and performance metrics. This builds trust with stakeholders and demonstrates your commitment to responsible practices (Silvius & Schipper, 2019).

4.1 The Synergy of Collaboration:

1) **Shared Sustainability Goals & Joint Initiatives:** Collaborative partnerships enable the development of mutually beneficial sustainability goals across the entire supply chain. This collaborative approach fosters a sense of collective responsibility and facilitates progress towards shared environmental and social objectives. Joint initiatives, such as implementing eco-

friendly packaging solutions or reducing carbon footprints within transportation networks, demonstrate the power of collective action (Brun et al., 2020).

2) Knowledge Sharing & Collaborative Innovation: Collaboration fosters a dynamic knowledge-sharing environment. Businesses can learn from each other's sustainability best practices, explore innovative technologies jointly, and co-create solutions to address critical environmental and social challenges faced within the supply chain (Mason, 2020). This cross-pollination of ideas fosters a culture of continuous improvement and accelerates progress towards a more sustainable future.

3) Proactive Risk Mitigation & Enhanced Supply Chain Resilience: Collaborative partnerships empower businesses to proactively mitigate risks. By openly communicating potential disruptions or resource scarcity challenges, stakeholders can develop contingency plans and ensure supply chain continuity in the face of unforeseen circumstances (Brun et al., 2020). This collaborative approach enhances overall supply chain resilience and strengthens the network's ability to adapt to evolving market dynamics.

4.2 Transparency: Building Trust and Accountability

1) Open Communication & Information Sharing: Transparency is the cornerstone of trust and accountability within the supply chain. Businesses committed to sustainability should openly communicate their sustainability goals, progress metrics, and any challenges encountered with all stakeholders – suppliers, customers, and investors alike (Mason, 2020). This transparency fosters trust and strengthens stakeholder relationships.

2) Supply Chain Visibility & Traceability: Implementing robust traceability systems empowers businesses to track materials and products throughout their journey within the supply chain. This granular visibility allows for informed decision-making, facilitates the identification of potential issues like unethical sourcing practices, and ensures responsible production processes throughout the network (Mason, 2020).

3) Stakeholder Engagement & Feedback Integration: Creating open communication channels with stakeholders allows businesses to receive valuable feedback on their sustainability efforts. This feedback is instrumental in driving continuous improvement and ensuring alignment with evolving stakeholder expectations. Integrating this feedback into business practices demonstrates responsiveness and a commitment to responsible operations (Silvius & Schipper, 2019).

4.3 The Competitive Advantage of Collaboration and Transparency:

1) Enhanced Sustainability Performance: Collaboration and transparency are key drivers of improved sustainability performance across the entire supply chain. Working together with stakeholders allows for a more holistic approach, tackling critical issues like climate change, resource depletion, and ethical labor practices with greater collective impact. This collaborative effort fosters a more sustainable future for all stakeholders.

2) Increased Supply Chain Resilience: Open communication and information sharing pave the way for proactive risk mitigation and faster response times to disruptions. This collaborative approach strengthens the supply chain's resilience and adaptability, allowing it to navigate unforeseen challenges with greater agility.

3) Improved Brand Reputation & Customer Loyalty: Consumers are increasingly drawn to brands demonstrating a commitment to sustainability. Implementing collaborative and transparent practices builds trust and strengthens brand reputation, leading to increased customer loyalty and a competitive advantage in the marketplace.

MITIGATING GREENHOUSE GAS EMISSIONS IN THE SUPPLY CHAIN: A MULTI-PRONGED APPROACH

Mitigating greenhouse gas emissions is a crucial aspect of environmental sustainability in supply chains. The strategies outlined in the previous section, such as sustainable procurement, sustainable product design, and transportation optimization, all contribute to reducing greenhouse gas emissions.

The imperative for businesses to minimize their environmental impact has become increasingly clear. This section explores a comprehensive framework for mitigating greenhouse gas (GHG) emissions across the entire supply chain. This framework addresses multiple aspects such as transport, energy use, and waste management to identify and implement strategies for reducing emissions at each stage of the supply chain, from sourcing materials to product delivery. Implementing strategies to reduce greenhouse gas emissions across the entire supply chain is essential for organizations to minimize their environmental impact. Furthermore, integrating sustainability practices into the supply chain can also lead to cost savings and operational efficiencies.

A. Transportation Optimization: Achieving Efficiency Through Logistics Innovation

Innovations in transportation optimization, particularly in logistics, play a vital role in enhancing efficiency. Studies highlight various strategies such as Collaborative Logistics (CL), chemical reaction optimization (CRO), and Blockchain technology to streamline supply chain networks and reduce costs while minimizing (Ghomi et al., 2023; Islam et al., 2020; Kiani Mavi et al., 2022). Implementing these strategies can lead to optimized route planning, reduced fuel consumption, and lower greenhouse gas emissions in transportation operations. These innovations focus on optimizing truck-goods assignments, improving transportation scheduling, and enhancing visibility across global supply chains. By leveraging technologies like artificial intelligence, machine learning, and blockchain, companies can achieve resilient and sustainable transport networks that operate effectively even during crises like COVID-19 pandemic. Implementing efficient logistic systems for handling solid municipal waste is also crucial, requiring the development of relevant models and algorithms for waste transportation and recycling. Overall, integrating innovative approaches in logistics is essential for achieving operational excellence and cost-effectiveness in transportation networks. Implementing efficient logistic systems and adopting innovative approaches in transportation optimization is crucial for businesses to minimize their environmental impact and achieve operational excellence.

B. Clean Energy Adoption: Powering the Supply Chain with Sustainability

Clean energy adoption is a key strategy for greening the supply chain and reducing greenhouse gas emissions. By transitioning to renewable energy sources such as solar, wind, and hydroelectric power, organizations can significantly decrease their carbon footprint and reliance on fossil fuels (Xin et al., 2022). This transition can be achieved through various means, including installing solar panels at facilities, utilizing electric vehicles for transportation, and partnering with renewable energy providers. Adopting clean energy in the supply chain is crucial for sustainability and reducing environmental impact (Huang et al., 2023; Sharma et al., 2023; Wangsa et al., 2022). It not only helps in reducing greenhouse gas emissions but also promotes energy independence and resilience. By generating renewable energy on-site, companies can reduce their dependence on fossil fuel-generated electricity and contribute to a cleaner energy grid (Patel et al., 2022). This transition to clean energy in the supply chain requires collaboration between stakeholders, including suppliers, manufacturers, logistics providers, and customers. Studies highlight the benefits of investing in green technologies for transportation and warehousing, showcasing cost savings, emission reductions, and lead-time improvements (Waqas et al., 2022). Implementing clean energy adoption in the supply chain is not only beneficial for the environment but also helps organizations achieve operational excellence and cost-effectiveness. Implementing clean energy adoption in the supply chain is crucial for sustainability, reducing greenhouse gas emissions, and minimizing environmental impact. It is important for organizations to prioritize clean energy adoption in their supply chains as a key strategy for achieving sustainability goals, reducing greenhouse gas emissions, and minimizing environmental impact. Furthermore, the importance of incorporating sustainable practices like lean, green, and agile supply chain strategies is evident in promoting green innovation, competitive advantage, and sustainable firm performance. Overall, leveraging clean energy sources and sustainable practices not only drives environmental benefits but also enhances operational efficiency and long-term viability in the supply chain. Implementing clean energy

adoption in the supply chain is crucial for organizations to achieve sustainability goals, reduce greenhouse gas emissions, and minimize environmental impact (Patel et al., 2022).

C. Production Process Efficiency: Minimizing Environmental Impact at the Source

Efficient production processes play a crucial role in minimizing environmental impact at the source. By focusing on resource efficiency, companies can reduce their ecological footprint and conserve natural resources (Krämer & Engell, 2018). This can be achieved through strategies such as optimizing production processes, implementing waste reduction measures, and promoting the use of renewable materials (Patel et al., 2022). Environmental requirements are increasingly shaping manufacturing practices, with a significant impact on areas like metallurgical technologies (Besta et al., 2022). Additionally, the adoption of circular economy principles can further enhance production process efficiency by promoting the reuse and recycling of materials, reducing waste generation, and minimizing the consumption of virgin resources. Implementing models like the two-stage DEA approach can help in reducing undesirable outputs and enhancing efficiency in environmental units within the production process (Zoriehhabib et al., 2021). Greening the supply chain through clean energy adoption and production process efficiency is vital for organizations to achieve sustainability goals, reduce greenhouse gas emissions, and minimize environmental impact (Patel et al., 2022). Incorporating environmental impact assessments in all phases of process chain planning, considering energy and resource efficiency, is vital for sustainable production and minimizing environmental impact (Denkena et al., 2022).

Eco-efficiency process-improvement methods, combining life cycle assessment results and production costs, can identify areas for improvement and trade-offs, guiding the eco-design of new processes and products (Piccinno et al., 2018). Overall, a holistic approach to production process efficiency is essential for mitigating environmental impact from the outset. Incorporating environmental impact assessments and adopting eco-efficiency process-improvement methods can help organizations minimize their ecological footprint and promote sustainability in the production chain (Miah et al., 2015). In conclusion, implementing strategies for production process efficiency is crucial for minimizing environmental impact at the source (Zailani et al., 2012).

The prior section meticulously outlined a multi-pronged framework for mitigating greenhouse gas emissions throughout the entire supply chain. This framework emphasized a holistic approach, focusing on critical areas such as transportation optimization, clean energy adoption, and production process efficiency. While these strategies provide a robust roadmap for emission reduction, their successful implementation requires practical considerations and real-world applications.

LEVERAGING TECHNOLOGICAL INNOVATIONS FOR SUSTAINABLE SUPPLY CHAINS

The adoption of cutting-edge technologies has emerged as a crucial enabler for organizations to achieve their sustainability goals within their supply chain operations. These innovative solutions offer a range of benefits, from enhancing traceability and transparency to optimizing logistics and minimizing environmental impact. Three prominent technologies driving sustainability in supply chains are blockchain, artificial intelligence (AI), and the Internet of Things (IoT). Table 1. show the impact of technological innovation on sustainable supply chain.

Table 1. Impact of Technological Innovations on Sustainable Supply Chains

Technology	Benefits	Challenges
Blockchain	<ul style="list-style-type: none"> - Improved traceability & provenance - Enhanced transparency & accountability - Facilitated compliance with sustainability standards (Kouhizadeh et al., 2021; Saberi et al., 2019)	<ul style="list-style-type: none"> - Interoperability issues - Scalability concerns - Resistance to adoption (Kshetri, 2021)

Table 2. (Cont.)

Technology	Benefits	Challenges
Artificial Intelligence	<ul style="list-style-type: none"> - Optimized transportation routes & fleet management - Reduced fuel consumption & emissions - Improved inventory management & demand forecasting (Sanders et al., 2019) 	<ul style="list-style-type: none"> - Data quality & availability concerns - Integration with existing systems - Skilled workforce requirements (Nozari et al., 2022)
Internet of Things	<ul style="list-style-type: none"> - Real-time environmental monitoring - Identification of inefficiencies & improvement opportunities - Facilitated compliance with environmental regulations (Yang et al., 2022) 	<ul style="list-style-type: none"> - Cybersecurity & data privacy concerns - Interoperability issues - Upfront costs (Yang et al., 2022)

Successful implementation of these technological innovations requires careful planning and a strategic approach. Organizations should assess their specific supply chain needs, identify potential use cases, and develop a roadmap for adoption. Additionally, fostering collaboration with technology providers, building in-house expertise, and ensuring data security and privacy are crucial for realizing the full potential of these innovations in achieving sustainable supply chain operations.

CASE STUDIES AND BEST PRACTICES

Companies can look to successful case studies and best practices for guidance on how to effectively implement strategies for production process efficiency and minimize environmental impact. For example, in the automotive industry, companies like Tesla have successfully implemented sustainable manufacturing practices by focusing on energy efficiency, reducing waste through recycling and reusing materials, and implementing renewable energy sources in their production facilities. Additionally, companies like Patagonia have prioritized sustainability in their supply chain by implementing initiatives like the Worn Wear program, which promotes the repair and reuse of products to extend their lifespan and reduce the need for new production. Implementing strategies for production process efficiency requires a comprehensive approach that considers energy and resource efficiency, incorporates environmental impact assessments, and utilizes eco-efficiency process-improvement methods (Miah et al., 2015).

Case Studies in Sustainable Supply Chain Leadership

Case studies in sustainable supply chain leadership provide valuable insights into overcoming barriers and enhancing sustainability practices across various industries. Studies like those focusing on multi-tier food supply chains (Oyedijo et al., 2024), heavy vehicle and equipment industry (Shekarian et al., 2022), shed light on the challenges faced and strategies employed. These cases highlight the importance of factors such as ethical leadership, circular supply chain practices, and alignment with sustainability practices within the entire supply chain. By examining these case studies and best practices, companies can gain insights into the strategies and approaches that have been successful in promoting sustainability in supply chains. These case studies offer practical implications for managers to improve sustainability performance, address barriers, and optimize sustainable supply chain management strategies that show in Table 2.

Table 3. Sustainability Case Studies

Company	Challenge	Strategies	Impact
Patagonia (O'Rourke & Strand, 2017; Schillmann, 2020)	Minimize environmental footprint and ensure ethical sourcing in the garment industry	<ul style="list-style-type: none"> - Focus on durable, repairable products - Take-back and repair programs - Use of recycled materials - Ethical sourcing 	Pioneer in circular economy practices and ethical labor standards in apparel industry
Tesla (Palmié et al., 2024; Yahdiyani et al., 2023)	Revolutionize transportation sector by reducing fossil fuel reliance	<ul style="list-style-type: none"> - Developing and manufacturing electric vehicles - Investing in battery technology - Building charging infrastructure 	Disruptive force accelerating shift to electric vehicles and fostering sustainable automotive industry
Unilever (Murphy & Murphy, 2018)	Integrate sustainability across vast, complex multi-product supply chain	<ul style="list-style-type: none"> - Setting sustainability goals - Sustainable sourcing - Eco-friendly packaging - Consumer education 	Benchmark for implementing comprehensive sustainability framework across global supply chains

These case studies that present in table 1 show how leading companies are implementing innovative strategies to achieve environmental and social responsibility. Remember, continuous improvement is essential. By learning from these leaders and adapting their successful approaches to your specific context, you too can contribute to building a more sustainable future.

Table 4. Thailand Sustainability Case Studies

Company	Strategies	Benefits	Challenges
Mitr Phol Sugar Group (Manivong & Bourgois, 2017)	<ul style="list-style-type: none"> - Precision farming techniques - Optimized resource usage (water, fertilizer) - Promotion of biodiversity - Renewable energy (biomass power) 	<ul style="list-style-type: none"> - Reduced water consumption (30%) - Lower greenhouse gas emissions (25%) - Cost savings 	<ul style="list-style-type: none"> - Training & capacity building for small farmers - Incentive programs for adoption
Indorama Ventures (Brooks et al., 2019)	<ul style="list-style-type: none"> - Recycled materials in production - Energy-efficient technologies - Responsible waste management - Renewable energy (solar power) - Bio-based & biodegradable packaging 	<ul style="list-style-type: none"> - Reduced energy consumption - Lower water usage - Less waste generation - Competitive advantage (sustainable products) 	<ul style="list-style-type: none"> - Coordination & training across facilities & suppliers - Investment in new technologies

These case studies (Table 3) highlight the real-world benefits of implementing sustainability strategies within Thai supply chains, such as resource efficiency, cost savings, and reduced environmental impact. They also demonstrate the challenges faced by companies in different sectors and the lessons learned, providing practical insights for readers interested in adopting sustainable supply chain practices.

BEST PRACTICES FOR BUILDING A SUSTAINABLE SUPPLY CHAIN

The table 5. present best practices for sustainable supply chain management. These practices can be categorized into four main areas: supplier engagement, supply chain transparency, optimizing for efficiency and circularity, and investing in green technologies.

Table 5. Sustainable Supply Chain Management: Key Practices

Best Practice	Description
Supplier Engagement	Conduct regular audits, establish collaborative partnerships, foster shared goals and accountability with suppliers (Correia et al., 2024)
Supply Chain Transparency	Map your supply chain, cultivate open communication with stakeholders to build trust and encourage collaboration (Shekarian et al., 2022).
Optimizing for Efficiency & Circularity	Conduct life cycle assessments, embrace circular economy principles by designing reusable and recyclable products (Correia et al., 2024)
Investing in Green Technologies	Explore energy-efficient technologies, renewable energy sources, and waste reduction programs (Correia et al., 2023).
Building a Broader Commitment	Partner with NGOs and sustainability organizations, implement data-driven practices to measure progress and ROI (Centobelli et al., 2023)

NAVIGATING THE GREEN PATH: CHALLENGES AND OPPORTUNITIES IN SUSTAINABLE SUPPLY CHAINS

The imperative for sustainability has become a cornerstone principle in modern supply chain management. Environmental concerns, consumer demands for eco-friendly products, and the need for long-term business resilience are driving organizations to adopt environmentally conscious practices. This shift presents a complex landscape with significant challenges, but also remarkable opportunities for those who embrace it.

Table 6. Sustainable Supply Chain Challenges and Opportunities

Category	Challenge	Opportunity	Benefit
Economic	Upfront investments in clean technologies, renewable energy, and responsible sourcing (Moxnes, 2023)	Implement eco-friendly technologies, sustainable materials, and circular economy principles (Correia et al., 2023)	Long-term cost savings through resource efficiency
Transparency	Difficulty tracking environmental impact across complex supply chains (Leal Filho et al., 2022)	Build robust traceability programs and collaborate with suppliers (Sarwar et al., 2021).	Enhanced brand reputation through demonstrably responsible practices

Table 7. (Cont.)

Category	Challenge	Opportunity	Benefit
Collaboration	Aligning interests of diverse stakeholders (Zarte et al., 2022)	Foster clear communication, a shared vision, and mutually beneficial solutions (Giuffrida & Mangiaracina, 2020).	Increased customer loyalty through transparency and ethical practices
Consumer Behavior	Price sensitivity and lack of awareness hindering market success of sustainable products sourcing (Moxnes, 2023).	Educate consumers about the value proposition and environmental benefits (Patel et al., 2022).	Competitive advantage by differentiating as environmentally responsible

In conclusion, while there are significant challenges on the road to sustainability, there are abundant opportunities for businesses that embrace sustainable supply chain practices. By addressing the challenges and seizing the opportunities, businesses can build a sustainable supply chain that not only benefits the environment and society but also leads to long-term business success.

POLICY AND REGULATORY LANDSCAPE FOR SUSTAINABLE SUPPLY CHAINS IN THAILAND

Thailand's commitment to sustainable development extends to its supply chains, evident in a robust policy framework. The National Economic and Social Development Plan prioritizes responsible resource management and green technologies across industries.

Government Agencies: The Ministry of Industry, through the Department of Industrial Works, spearheads sustainability efforts by establishing regulations promoting eco-friendly practices, waste management, and energy efficiency across sectors like automotive, electronics, and food processing. The Ministry of Energy complements these efforts by offering incentives that encourage businesses to adopt renewable energy sources in their supply chain operations. Additionally, the Ministry of Agriculture and Cooperatives plays a vital role in promoting sustainable agricultural practices, organic farming, and responsible resource utilization within the agricultural supply chain.

Industry Associations: Industry associations actively participate in advancing sustainable practices among their members. The Federation of Thai Industries (FTI) provides guidance, training, and support for implementing green supply chain initiatives encompassing sustainable sourcing, eco-friendly production processes, and responsible waste management. Similarly, sector-specific associations such as the Thai Automotive Industry Association (TAIA) (Ghazali et al., 2011) and the Thai Electrical and Electronics Institute (EEI) encourage sustainable practices within their respective domains (Manomaivibool & Vassanadumrongdee, 2011), focusing on areas like the use of eco-friendly materials, energy-efficient manufacturing, and responsible end-of-life vehicle and e-waste management, respectively.

International Standards: Thailand demonstrates its commitment to global best practices by adopting international sustainability standards. The ISO 14001 standard for environmental management systems (Bravi et al., 2020) provides a framework for businesses across sectors to measure and improve their environmental performance within their supply chains. Additionally, the Global Reporting Initiative (GRI) standards for sustainability reporting (Petera & Wagner, 2015) have been embraced by Thai companies, enhancing transparency and accountability in their sustainability practices and supply chain operations.

RECOMMENDATIONS FOR POLICYMAKERS

To further solidify Thailand's position as a leader in sustainable supply chain management, policymakers can consider several recommendations.

1) Strengthen environmental regulations and enforcement mechanisms to ensure compliance across all sectors and supply chain stages, including stricter penalties for non-compliance.

2) Introduce financial incentives, such as tax breaks or subsidies, for businesses investing in sustainable technologies, renewable energy sources, and eco-friendly supply chain practices.

3) Facilitate public-private partnerships and collaborations between government agencies, industry associations, and businesses to promote knowledge sharing, technology transfer, and best practice adoption in sustainable supply chain management.

4) Support the development of eco-industrial parks and green logistics hubs, providing infrastructure and incentives to create sustainable supply chain ecosystems.

5) Enhance stakeholder engagement and public awareness campaigns to increase consumer demand for sustainable products and services, driving market-based incentives for businesses to adopt green supply chain practices.

6) Encourage the adoption of international sustainability standards and certifications, such as ISO 14001 and GRI, to align Thai supply chains with global best practices and facilitate integration into international markets.

By leveraging the roles of government agencies, industry associations, and international standards, and implementing policy recommendations, Thailand can create a conducive environment for businesses across sectors to prioritize sustainability in their supply chain operations.

GLOBAL SUPPLY CHAIN INTERCONNECTIONS AND THAILAND'S ROLE IN THE GLOBAL SUSTAINABILITY LANDSCAPE

Thailand's Role in Global Sustainable Supply Chains

As a major manufacturing and exporting hub, Thailand's sustainability practices have far-reaching implications that extend beyond its borders. The country's supply chain ecosystem is deeply interconnected with global supply chain dynamics, influenced by international standards, collaborations, and market demands.

Aligning with International Standards and Certifications

To maintain competitiveness in global markets, Thai companies have recognized the importance of adhering to internationally recognized sustainability standards and certifications. These include the ISO 14001 environmental management system standard (Bravi et al., 2020), the Global Reporting Initiative (GRI) sustainability reporting framework (Peters & Wagner, 2015), and industry-specific certifications like the Responsible Business Alliance (RBA) Code of Conduct for the electronics industry (Neves, 2018).

Compliance with these standards not only enhances credibility and transparency but also facilitates integration into global supply chains, where sustainability performance is increasingly scrutinized by multinational corporations and conscious consumers.

Fostering International Collaborations

Sustainable supply chain management requires a collaborative approach that transcends national boundaries. Thailand has actively participated in international initiatives and partnerships aimed at promoting sustainability in supply chains.

For instance, the Thai government has partnered with the United Nations Development Programme (UNDP) to implement the Thailand Sustainable Supply Chain Transformation (Thai-SSCT) project, which aims to enhance the competitiveness of Thai businesses by adopting sustainable practices across various industries, including agriculture, manufacturing, and tourism.

Additionally, Thai companies have collaborated with global organizations such as the World Business Council for Sustainable Development (WBCSD)(Nelson & Grayson, 2017) and the Sustainable Apparel Coalition (SAC) (Poldner, 2017) to share best practices, access research and resources, and contribute to the development of industry-wide sustainability frameworks.

Contributing to Global Sustainability Initiatives

Thailand's efforts towards sustainable supply chains also contribute to broader global sustainability initiatives and goals. For example, the country's commitment to reducing greenhouse gas emissions and transitioning to renewable energy sources aligns with the Paris Agreement's objectives and supports the United Nations' Sustainable Development Goals (SDGs)(Carlsen & Bruggemann, 2022), particularly those related to climate action and responsible consumption and production.

Furthermore, Thailand's emphasis on sustainable agriculture practices, such as organic farming and responsible resource management, supports global efforts to ensure food security and promote sustainable food systems.

By aligning with international standards, fostering collaborations, and contributing to global sustainability initiatives, Thailand can position itself as a responsible and influential player in the global sustainable supply chain landscape. This not only enhances the country's competitiveness and reputation but also contributes to the collective effort towards a more sustainable and resilient global economy.

IMPLICATIONS AND FUTURE RESEARCH

The long-term viability of Thailand's manufacturing sector hinges on a comprehensive approach to sustainability. Strategic investments in renewable energy technologies, the implementation of environmentally friendly manufacturing processes, and the adoption of digitalization and smart technologies are paramount. Additionally, exploring the use of sustainable materials and packaging, promoting sustainable agricultural practices, and bolstering climate change adaptation strategies are crucial for solidifying Thailand's position as a leader in sustainable manufacturing.

To further solidify Thailand's position as a leader in sustainable manufacturing, future research initiatives should prioritize three key areas:

1. Optimizing Sustainable Supply Chain Management:
 - Develop and implement energy-efficient Internet of Things (IoT) solutions tailored for supply chain monitoring and optimization.
 - Expand the scope and applications of sustainable green logistics and remanufacturing practices to enhance efficiency and reduce environmental impact.
 - Refine frameworks for measuring and evaluating the sustainability of supply chains to ensure accurate assessment and continual improvement.
2. Enhancing Renewable Energy Systems:
 - Research methods to optimize the economic operation of renewable energy systems, with a focus on maximizing efficiency and cost-effectiveness.
 - Explore the development of intelligent power-routing microgrid frameworks to create a more resilient and sustainable energy infrastructure.
3. Fostering Greener Technologies and Business Practices:
 - Emphasize the pivotal role of knowledge, innovation, and entrepreneurship in driving the development and adoption of sustainable technologies.
 - Investigate strategies for the decarbonization of manufacturing operations to mitigate environmental impact and promote sustainability.
 - Explore the implementation of circular economy models within Thailand's manufacturing sector to minimize waste and maximize resource efficiency.
 - Research the digitalization of logistics and supply chain management to facilitate the adoption of climate-neutral business practices and enhance overall sustainability.

Focusing research efforts on these critical areas will not only bolster Thailand's leadership in sustainable manufacturing but also pave the way for a more environmentally sustainable future

CONCLUSION

The integration of sustainability into supply chain management has evolved into an imperative in today's business landscape. Environmental concerns, coupled with consumer demands and the pursuit of long-term resilience, have reshaped organizational priorities, rendering the adoption of green practices across supply chains not merely an option but a necessity.

This comprehensive study underscores the critical importance of sustainable supply chain practices, encompassing sustainable procurement, product design, optimized logistics, clean energy adoption, and waste reduction strategies. Through the implementation of these approaches, organizations can effectively address environmental challenges, curb greenhouse gas emissions, and transition towards greener and more responsible supply chain operations.

The benefits of integrating sustainability into supply chains are diverse, spanning from enhanced brand reputation and increased customer loyalty to cost savings through resource efficiency, improved risk management, fostered innovation, and a competitive advantage in the marketplace. Case studies of industry leaders exemplify the potential of pioneering sustainable models, such as circular economies, renewable energy integration, and comprehensive green frameworks.

Thailand, as a major manufacturing and export hub, plays a pivotal role in accelerating the transition towards more sustainable supply chains. The country's contributions across industries like automotive, electronics, and agriculture position it as a leader in embracing sustainable practices within its supply chain ecosystems. This not only aligns with rising consumer expectations but also solidifies Thailand's reputation as a responsible steward of environmental stewardship on the global stage.

Despite persistent challenges, including economic barriers, transparency issues, and complexities in stakeholder collaboration, the opportunities presented by sustainable supply chains are significant and far-reaching. Addressing these challenges through collaborative efforts, policy support, and the adoption of innovative technologies can unlock the full potential of sustainable supply chain management.

As the world grapples with pressing issues like climate change, resource depletion, and environmental degradation, the imperative for sustainable supply chain practices has never been more evident. Therefore, it is imperative for organizations, policymakers, and stakeholders to embrace this paradigm shift, fostering a more sustainable and resilient future for supply chains, businesses, and the planet we share.

Recommendations

To advance sustainable supply chain practices, collaborative efforts among stakeholders are essential. Addressing transparency issues and promoting information sharing across supply chains can foster a culture of collaboration, leading to more effective implementation of sustainable practices. Additionally, policymakers should consider implementing incentives to encourage businesses to adopt sustainable practices. This could include tax incentives for investments in environmentally friendly initiatives or subsidies for companies transitioning to renewable energy sources. By aligning financial incentives with sustainability goals, governments can accelerate the adoption of green practices in the business sector. Furthermore, investments in research and development are crucial for driving innovation in sustainable technologies and practices. Particularly, focusing on areas such as renewable energy integration and circular economy models can pave the way for more efficient resource utilization and waste reduction. Industry-wide initiatives and partnerships are also key to scaling up sustainable supply chain practices. By collaborating across sectors, businesses can share best practices, pool resources, and collectively work towards achieving sustainability goals. Lastly, enhancing education and awareness programs is essential for empowering stakeholders with the knowledge and skills needed to embrace sustainable supply chain practices effectively. By providing training and

educational resources, organizations can ensure that individuals are equipped to make informed decisions and contribute to positive environmental outcomes.

CONFLICTS OF INTEREST

The author declares that there are no conflicts of interest found in this research.

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