

Green Innovation in Supply Chain Management

Nguyen Manh Ha¹, Phan Thanh Tung², Hoang Hai Anh³, Tran Thu Phuong⁴

1Green Yellow Viet Nam Limited Liability Company

2British International School Hanoi

3Newton High School

4Ha Long High School for the Gifted

Abstract: The article emphasizes the importance of green manufacturing and sustainable supply chain management in minimizing environmental impact, conserving resources, and enhancing sustainability. It outlines key practices such as waste reduction, renewable energy integration, and circular economy principles. The article also highlights the economic, environmental, and social benefits of green manufacturing, including cost savings, reduced emissions, and improved brand reputation. Challenges like high initial costs and the need for employee training are acknowledged, but also the long-term advantages of adopting green practices and the essential role of innovation and collaboration in advancing sustainability.

1. INTRODUCTION

In today's fast-paced global economy, the focus on sustainability and environmental stewardship has become more critical than ever before. As the world grapples with the challenges of climate change, resource depletion, and environmental degradation, businesses are under increasing pressure to adopt practices that minimize their ecological footprint. This growing awareness has led to a significant shift in how companies operate, with a stronger emphasis on integrating green innovation and sustainable practices into every aspect of their business models. One of the most influential areas where this integration can create a substantial positive impact is supply chain management [1]. By rethinking and restructuring supply chains to prioritize environmental considerations, companies can drive significant advancements in sustainability. Central to this effort is the adoption of green manufacturing practices, which not only reduce waste and energy consumption but also contribute to the overall resilience and competitiveness of businesses in an increasingly eco-conscious market. Through these practices, companies are not just responding to regulatory pressures but are also positioning themselves as leaders in the movement toward a more sustainable and responsible global economy.

2. LITERATURE REVIEW

Green innovation in supply chain management (SCM) is essential for sustainability and competitive advantage. Companies face growing pressure from governments, consumers, and stakeholders to adopt eco-friendly practices.

Regulatory pressures, market demands, and corporate social responsibility (CSR) are among the primary drivers pushing companies toward green innovation. Businesses are increasingly adopting sustainable practices not only to comply with environmental regulations but also to meet the growing consumer demand for eco-friendly products [2]. These initiatives help organizations enhance their brand image and foster goodwill among stakeholders. For companies looking to remain competitive, green innovation has become a crucial aspect of their strategic planning. Green

procurement, which involves sourcing materials with lower environmental impacts, is one commonly adopted practice. Another key strategy is eco-design, where products are designed from the ground up with sustainability in mind. In addition, reverse logistics, the process of reclaiming used products for reuse or recycling, has gained traction. Cleaner production processes also aim to reduce emissions and waste, further minimizing the environmental footprint of businesses.

However, the path to adopting green innovation is not without its challenges. For many organizations, especially small and medium enterprises (SMEs), the high costs associated with implementing sustainable practices pose a significant hurdle. Investing in cleaner technologies, redesigning supply chains, and retraining staff can demand considerable financial resources. Furthermore, the absence of standardized sustainability metrics makes it difficult for businesses to measure their environmental impact effectively. Without clear benchmarks, organizations struggle to track progress and demonstrate the tangible benefits of their green initiatives. Resistance to change is another major barrier [3]. Stakeholders, including employees, suppliers, and even customers, may be reluctant to embrace new, greener processes. This reluctance often stems from a fear of disruption, a lack of knowledge, or perceived risks associated with adopting untested methods. As a result, many companies face internal and external pushback when trying to implement green innovation strategies [4].

Despite these challenges, the benefits of green innovation are becoming increasingly evident. By adopting environmentally friendly practices, companies can significantly reduce operational costs. For instance, energy-efficient processes and waste-reduction efforts often lead to savings in production costs. Green innovation also improves resource efficiency, allowing companies to get more out of fewer materials, which can lead to long-term sustainability. Moreover, businesses that prioritize sustainability often see an improvement in their brand reputation, attracting eco-conscious consumers and investors alike [5]. In addition to the cost savings and brand enhancements, green innovation opens up new market opportunities. Companies that lead in

sustainability are often able to tap into emerging markets for green products and services. These organizations are seen as pioneers, setting industry standards for what it means to be environmentally responsible. By positioning themselves as leaders in green innovation, businesses can secure a competitive advantage, driving long-term growth and profitability.

Looking ahead, the future of green innovation seems promising with the advent of emerging technologies. Blockchain, for example, offers new possibilities for improving transparency and traceability within green supply chains. This technology allows stakeholders to verify the sustainability credentials of products and processes in real-time. Similarly, the Internet of Things (IoT) can enhance operational efficiency by enabling smarter resource management and real-time monitoring of environmental impacts [6].

As these technologies continue to evolve, they will likely open new avenues for research and innovation, further advancing the field of green innovation. Companies that invest in these emerging tools will be better equipped to meet the increasing regulatory demands and consumer expectations for sustainability[7].

3. THEORETICAL BACKGROUND AND HYPOTHESES DEVELOPMENT

Green innovation in supply chain management (SCM)

Green manufacturing is an integrated approach that focuses on reducing the environmental impact of production processes by considering sustainability at every stage. It aims to minimize the use of non-renewable resources, conserve energy, and limit waste generation. By incorporating practices such as waste reduction, recycling, and the use of eco-friendly raw materials, green manufacturing ensures that products are made in a way that minimizes harm to the environment. For example, in the design phase, products are developed with an emphasis on durability and recyclability, ensuring that fewer materials are used and that those materials can be reused or safely disposed of at the end of the product's life [8]. Throughout the production process, companies strive to reduce their carbon emissions, limit water usage, and decrease energy consumption. Technologies like renewable energy sources and cleaner production methods play a significant role in achieving these goals. In addition, green manufacturing promotes responsible sourcing of materials, often prioritizing suppliers who also adhere to sustainable practices. This holistic approach not only addresses the environmental impact of production but also considers the social and economic aspects, ensuring that the process supports long-term sustainability. Ultimately, green manufacturing is about creating products that benefit society while minimizing the ecological footprint throughout their lifecycle—from resource extraction to disposal [9].

Green innovation plays a pivotal role in driving the transition toward sustainable manufacturing, serving as a cornerstone

for businesses aiming to thrive in an eco-conscious world. This form of innovation involves not only the development of new products but also the reimagining of processes and services that deliver substantial environmental benefits. In the manufacturing sector, green innovation often translates to the adoption of energy-efficient production techniques, the use of renewable resources, and the minimization of waste throughout the production cycle. By incorporating green practices, companies can significantly reduce their carbon footprint, lowering emissions and conserving natural resources. For example, switching to cleaner energy sources such as solar or wind power can drastically cut down operational costs while simultaneously reducing a company's impact on the environment. Additionally, the development of eco-friendly products, such as biodegradable packaging or energy-saving appliances, meets the growing consumer demand for sustainable alternatives [11]. Moreover, green innovation fosters the introduction of cutting-edge technologies like automation and AI, which can optimize resource use and streamline manufacturing processes, further contributing to environmental sustainability. In a market that increasingly prioritizes sustainability, businesses that fail to innovate in this space risk being left behind. Thus, for companies seeking to maintain competitiveness, green innovation is not just an option but an essential strategy for long-term success in a rapidly evolving global market[12].

Advancing Sustainable Supply Chain Management

Sustainable supply chain management (SSCM) is a holistic approach that integrates environmental, social, and ethical considerations into every stage of the supply chain. The primary goal of SSCM is to reduce the overall ecological footprint, starting from the responsible sourcing of raw materials to the final delivery of products to consumers. This involves a concerted effort to ensure that suppliers and partners across the supply chain follow sustainable practices. For example, companies may choose to work with suppliers that prioritize renewable resources or employ energy-efficient technologies. In addition to sustainable sourcing, SSCM emphasizes reducing emissions during transportation, which is a significant contributor to global greenhouse gas emissions[13]. By optimizing logistics, using cleaner transportation methods, and reducing the distance that goods travel, companies can significantly lower their carbon footprint. Furthermore, SSCM encourages the improvement of energy efficiency in production processes, whether through the adoption of renewable energy, recycling initiatives, or more efficient manufacturing techniques. Beyond environmental benefits, SSCM also addresses social issues, such as ensuring fair labor practices and ethical sourcing. Businesses that adopt SSCM contribute not only to global sustainability efforts but also gain a competitive edge by improving operational efficiency, enhancing their brand reputation, and building stronger relationships with conscious consumers and stakeholders. By embracing SSCM, companies position themselves as leaders in responsible

business practices, driving both economic success and environmental stewardship [14].

The multifaceted benefits of green manufacturing span across several key areas, including environmental, economic, and social dimensions. Implementing green manufacturing practices not only helps companies reduce their ecological footprint but also contributes to broader sustainability goals. Green manufacturing offers significant environmental benefits. By conserving natural resources, reducing greenhouse gas emissions, and minimizing waste, companies contribute to the global effort to combat climate change. These practices help preserve ecosystems and reduce the depletion of essential resources, making green manufacturing an integral part of environmental conservation efforts. Economically, while the initial investment in green technologies may be high, the long-term financial gains are substantial. Businesses can lower operational costs by improving energy efficiency, reducing waste management expenses, and optimizing resource use. Moreover, producing sustainable products can attract a growing segment of eco-conscious consumers, unlocking new market opportunities and increasing profitability. Socially, companies that adopt green manufacturing enhance their brand reputation and foster stronger relationships with consumers and stakeholders. By aligning with corporate social responsibility (CSR) initiatives, they demonstrate a commitment to social and environmental well-being, reinforcing trust and loyalty. This dedication not only benefits communities but also positions companies as leaders in responsible business practices, promoting a sustainable future for both society and the planet [15].

Critical Factors in Advancing Green Manufacturing

Several key factors are essential in driving the success of green manufacturing initiatives. First and foremost is the commitment from leadership. Strong support from top management ensures that sustainability goals are prioritized and integrated into the company's overall strategy. Without this, green initiatives may lack the necessary resources or direction to succeed. Equally important is the adoption of advanced technology. Green manufacturing often relies on innovative technologies to improve energy efficiency, reduce waste, and lower emissions. Companies that invest in research and development to explore cleaner production methods will find it easier to achieve their sustainability goals. Another crucial factor is collaboration across the supply chain. Green manufacturing requires cooperation not only within the organization but also with suppliers and partners. Establishing clear sustainability criteria for suppliers helps ensure that the entire supply chain adheres to environmentally friendly practices. In addition, regulatory support plays a pivotal role. Government policies that promote green technology adoption and offer incentives for sustainability initiatives can significantly boost green manufacturing efforts [16].

Finally, market demand for sustainable products acts as a strong motivator for companies to adopt green manufacturing practices. As consumers increasingly prefer environmentally friendly products, businesses that align their practices with these preferences can gain a competitive edge, ensuring the long-term success of their green initiatives.

4. FINDINGS

4.1 SUSTAINABLE SOURCING AND PROCUREMENT: LAYING THE GROUNDWORK FOR A GREEN SUPPLY CHAIN

a. Strategic Supplier Partnerships:

Establishing partnerships with suppliers who adhere to environmentally sustainable practices is foundational to building a green supply chain. For instance, companies like Unilever have implemented supplier codes of conduct that require adherence to environmental and social sustainability standards. By selecting suppliers who are certified by organizations such as the Forest Stewardship Council (FSC) or the Fair Trade Certification, businesses can ensure that their procurement processes support sustainable sourcing.

b. Environmentally Preferable Raw Materials:

Pioneering the use of recycled materials in products, such as recycled polyester from plastic bottles, is one example of prioritizing raw materials with lower environmental footprints. This approach not only aligns with circular economy principles but also resonates with consumers who are increasingly seeking eco-friendly products.

c. Supplier Audits and Sustainability Assessments:

Conducting regular sustainability audits of suppliers is crucial for maintaining a green supply chain. For example, IKEA performs extensive audits on its suppliers to ensure compliance with its IWAY Standard, which covers environmental, social, and working conditions. These audits help identify areas for improvement and ensure that suppliers continuously adhere to green practices, fostering a culture of sustainability throughout the supply chain.

4.2 ECO-FRIENDLY MANUFACTURING PROCESSES: DRIVING EFFICIENCY AND SUSTAINABILITY

a. Enhancing Energy Efficiency:

Investing in energy-efficient manufacturing technologies, such as high-efficiency motors and LED lighting, can significantly reduce energy consumption. Some production facilities utilize renewable energy sources like solar and wind power, significantly reducing greenhouse gas emissions. Implementing similar energy management systems can help other companies monitor and optimize their energy use in real-time, leading to cost savings and reduced environmental impact.

b. Implementing Waste Reduction Strategies:

Lean manufacturing principles, such as those employed by companies like Nestlé, focus on minimizing waste and maximizing efficiency. Nestlé's factories have achieved zero waste-to-landfill status by implementing comprehensive recycling programs and repurposing materials that would otherwise be discarded. By applying these principles, companies can drastically reduce waste, contributing to a more sustainable manufacturing ecosystem while also reducing costs associated with waste disposal.

c. Innovative Water Conservation Techniques:

In water-intensive industries like beverage manufacturing, companies such as Coca-Cola have adopted water conservation technologies like closed-loop water systems and advanced filtration methods. These innovations have enabled Coca-Cola to reduce its water usage significantly and recycle up to 94% of the water used in its manufacturing processes. Similar approaches can be adopted by other companies to minimize water usage and wastewater generation, particularly in regions facing water scarcity or stringent regulatory requirements.

4.3 GREEN LOGISTICS AND TRANSPORTATION: MINIMIZING THE SUPPLY CHAIN'S CARBON FOOTPRINT

a. Optimizing Transportation Networks:

Advanced logistics planning tools, like those used by Amazon, optimize transportation routes to reduce fuel consumption and emissions. Amazon's logistics network utilizes real-time data from GPS and telematics systems to streamline delivery routes, enhancing efficiency and reducing the carbon footprint. Other companies can adopt similar technologies to optimize their logistics operations, achieving significant environmental and economic benefits.

b. Transitioning to Sustainable Transport Modes:

Investing in alternative transportation modes, including alternative fuel and advanced technology vehicles, can lower environmental impact. Shifting to more sustainable transportation modes, such as rail or sea freight for long distances and electric vehicles for local deliveries, can drastically reduce the carbon footprint of supply chains.

c. Optimizing Load Capacities for Efficiency:

Implementing load optimization strategies to maximize transportation efficiency, ensuring that trucks are fully loaded, reduces the number of trips and minimizes empty runs. By optimizing load capacities, companies can achieve significant cost savings while also lowering their environmental impact.

4.4 SUSTAINABLE PACKAGING: REDUCING ENVIRONMENTAL IMPACT AT THE PRODUCT LEVEL

a. Minimizing Packaging Materials:

Innovative companies like Apple have taken steps to reduce packaging materials by employing minimalist designs that still offer product protection. Apple's shift to more compact packaging for its products has reduced material usage and decreased the overall environmental footprint. By designing packaging that uses fewer materials, other companies can achieve similar reductions in waste and costs.

b. Adopting Eco-Friendly Packaging Materials:

The use of recyclable and biodegradable materials is becoming increasingly common, offering sustainable alternatives to traditional plastics. These biodegradable materials can be composted after use, reducing environmental impact. Companies that adopt such eco-friendly packaging solutions can meet consumer demand for sustainable products and comply with stricter environmental regulations.

c. Implementing Reusable Packaging Systems:

Reusable packaging systems, which allow consumers to return packaging for refilling and reuse, can significantly reduce waste and costs associated with single-use packaging, while also fostering customer loyalty through innovative and sustainable practices.

4.5 LIFECYCLE MANAGEMENT AND PRODUCT STEWARDSHIP: ENSURING END-TO-END SUSTAINABILITY

a. Comprehensive Lifecycle Analysis (LCA):

Conducting lifecycle analysis is essential for companies like Levi Strauss & Co., which has used LCA to understand the environmental impact of its products from raw material extraction to disposal. The company has identified areas for improvement, such as reducing water usage in denim production, and made data-driven decisions to enhance sustainability. Other companies can benefit from similar LCA practices, ensuring that sustainability is embedded at every stage of the product lifecycle.

b. End-of-Life Management Programs:

Implementing take-back and recycling programs that encourage customers to return used products for recycling can reduce e-waste and contribute to a circular economy. By developing similar end-of-life management programs, companies can ensure that their products are responsibly disposed of or recycled, minimizing environmental impact.

c. Designing for Disassembly and Reuse:

Products designed for disassembly are easier to recycle or refurbish at the end of their life. By adopting design-for-disassembly principles, companies can enhance the sustainability of their products and contribute to a circular economy.

4.6 LEVERAGING INFORMATION TECHNOLOGY AND SMART MANUFACTURING: INNOVATING FOR SUSTAINABILITY

a. Integration of IoT and Real-Time Monitoring:

Integrating IoT devices into manufacturing processes to monitor energy usage and equipment performance in real-time enables companies to quickly identify inefficiencies and optimize operations, reducing energy consumption and environmental impact.

c. Utilizing Data Analytics for Supply Chain Optimization:

Data analytics is critical for optimizing supply chain operations, ensuring that products are delivered efficiently while minimizing waste and emissions. Companies can leverage data analytics to make informed decisions that enhance the sustainability of their supply chains.

4.7 COLLABORATION AND STRATEGIC PARTNERSHIPS: ADVANCING INDUSTRY-WIDE SUSTAINABILITY

a. Fostering Industry Collaboration:

Collaborative initiatives, such as the Sustainable Apparel Coalition, bring together companies across the apparel industry to share best practices and drive collective progress toward sustainability goals. By participating in industry collaborations, companies can accelerate the adoption of green manufacturing practices and set new standards for environmental responsibility.

b. Engagement with Government and NGOs:

Partnerships with government agencies and non-governmental organizations (NGOs) can provide valuable support for green initiatives. For example, the U.S. Environmental Protection Agency's (EPA) SmartWay program helps companies reduce transportation emissions through innovative strategies and partnerships. By engaging with such programs, companies can access funding, regulatory guidance, and opportunities to participate in broader sustainability efforts.

c. Educating and Engaging Consumers:

Educating and engaging consumers about sustainability efforts through transparent communication and eco-friendly product offerings can build strong customer loyalty and drive demand for sustainable products. By similarly educating consumers about green manufacturing practices, companies can enhance their brand reputation and attract environmentally conscious customers.

4.8 EMPLOYEE TRAINING AND ORGANIZATIONAL CULTURE: EMBEDDING SUSTAINABILITY IN THE CORPORATE DNA

a. Developing Comprehensive Sustainability Training Programs:

Companies like Starbucks have implemented extensive sustainability training programs for their employees, ensuring that everyone in the organization is aligned with their

environmental goals. These programs should not only impart knowledge about environmental sustainability but also highlight the strategic importance of aligning operational practices with corporate sustainability objectives. By ensuring that all employees, from entry-level staff to senior management, are well-versed in sustainable methodologies, organizations.

b. Active Employee Involvement and Innovation Platforms:

Encouraging active participation from employees in sustainability initiatives is crucial for embedding green practices into the fabric of the organization. Creating platforms where employees can contribute ideas, propose improvements, and collaborate on sustainability projects empowers them to take ownership of the company's environmental goals. Such involvement can lead to innovative solutions that enhance the efficiency and effectiveness of sustainable practices throughout the supply chain. By leveraging the diverse perspectives and expertise of their workforce, companies can accelerate the adoption of green manufacturing techniques and drive continuous improvement.

c. Cultivating a Sustainability-Driven Organizational Culture:

Fostering a strong culture of sustainability is paramount for ensuring the long-term success of green manufacturing initiatives. This involves recognizing and rewarding employees and teams who make significant contributions to sustainability goals, thereby motivating the workforce to remain committed to these principles. By integrating sustainability into the core values of the organization and consistently reinforcing its importance, companies can create an environment where sustainable practices are not just encouraged but are an integral part of the organizational identity. Such a culture will support the seamless integration of green manufacturing practices into the supply chain, driving both environmental and economic benefits.

4.9 CHALLENGES AND FUTURE DIRECTIONS IN GREEN MANUFACTURING AND SUPPLY CHAIN MANAGEMENT

The transition to green manufacturing, while replete with substantial benefits, presents a series of significant challenges that must be strategically addressed within the framework of supply chain management. Among the most prominent obstacles are the substantial initial capital investments required for the acquisition and integration of advanced, environmentally friendly technologies. These financial outlays can be particularly burdensome for small to medium-sized enterprises. Furthermore, the shift towards green manufacturing necessitates extensive employee training programs, aimed at equipping the workforce with the skills and knowledge necessary to operate and maintain new technologies and processes. This educational component is essential but can be resource-intensive, requiring both time and monetary investment. Additionally, the adoption of green practices may disrupt established supply chain processes,

leading to potential inefficiencies or delays as companies recalibrate their operations to align with sustainability objectives.

Nevertheless, the urgency of embracing sustainable practices is underscored by the growing consumer demand for eco-friendly products and the increasing regulatory pressures mandating environmental responsibility. Companies that delay or resist the transition to green manufacturing and sustainable supply chain practices risk not only falling behind in a competitive marketplace but also facing potential legal and reputational consequences.

Looking ahead, the future of green manufacturing and its integration into supply chain management hinges on relentless innovation and strategic collaboration. Continuous advancements in technology, particularly in the realms of more efficient renewable energy sources and the application of artificial intelligence to optimize production and logistics processes, will be pivotal in overcoming current challenges. These technologies offer the potential to enhance both the environmental and economic performance of supply chains. Moreover, the successful adoption and scaling of green practices will require concerted efforts across industries and close partnerships with governmental bodies and non-governmental organizations. Such collaborations will be crucial in setting industry standards, sharing best practices, and securing the necessary resources for sustainable innovation.

5. CONCLUSION

In conclusion, the integration of green innovation and sustainable supply chain management is not merely a trend but a fundamental shift that will define the future of manufacturing. By committing to the development and implementation of green manufacturing practices, companies can not only reduce their environmental footprint but also realize significant economic benefits, such as cost savings and access to new markets. Moreover, meeting the escalating consumer demand for sustainable products will be vital for maintaining competitive advantage in a rapidly evolving global market. While the challenges associated with this transition are substantial, the long-term benefits far outweigh the initial costs, heralding a more sustainable and prosperous future for businesses that choose to lead in this space.

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