"BUILDING SMART SUPPLY CHAIN FOR GREEN BUSINESS"

Research Paper

Dr. Abhishek Mishra, SSBM, Geneva, Switzerland, abhisekmisra@gmail.com

Dr. Anna Provodnikova, SSBM, Geneva, Switzerland, anna@ssbm.ch

"Abstract"

The supply chain is global for modern businesses. The business in one country imports raw materials from another faraway country where it gets the raw materials in best available price. The products are manufactured at a factory and are shipped to markets across the globe where there is a demand. The raw materials and the finished products are shipped in cargo vessels in the sea or trucks on the land adding to the carbon footprint and has an impact on the environment. The packaging materials used are not ecofriendly. In this paper, a threefold approach is discussed that enable smart supply chain to make businesses green, sustainable and ecofriendly. The threefold approach includes Near Shoring, Eco-Friendly Packaging and Leveraging Technology,

Keywords: Green Business, Smart Supply Chain, Near Shoring, Eco-Friendly Packaging, Green Technology

1 Introduction

Modern businesses contribute to high level of carbon emissions not just because of industrial production but also due to supply chain. Not just green practices in manufacturing but also sustainable initiatives in supply chain plays a major role to reduce carbon footprint. Major nations across the globe have signed the UN Paris Accord 2016 to adopt greeners practices to reduce carbon footprint. Sustainable supply chain practices can help reduce carbon footprint to a great extent. Production and manufacturing units produce carbon dioxide as direct emissions while the supply chain contributes to indirect emission of carbon dioxide via the mode of transportation and non-enviromental friendly packaging (Ghosh *et al.*, 2020).

Manufacturing units procure cheaper raw materials from far away locations. Finished goods are shipped across the globe where there is a market demand for the goods. The whole product life cycle involves transporting raw materials and finished goods using trucks and ships that adds to carbon footprint. However, reshoring and nearshoring strategies can be used to source raw materials from nearby locations or from local suppliers and produce goods near to the demand market can help reduce carbon footprint (Fernández-Miguel *et al.*, 2022).

Packaging is an important aspect of supply chain. Goods are packaged before they are moved across the supply chain. Packaging is mostly done using plastic as it is light weight, cheap and high strength. But plastic is not environment friendly. Biodegradable packaging materials like cardboard can be used instead. Use of ecofriendly packaging material can reduce carbon footprint. Using ecofriendly, light weight packaging materials as an alternate to plastic packaging can help reduce carbon footprint (Silva and Molina-Besch, 2023).

Use of technology can bring down carbon footprint. Artificial Intelligence can be used to spot high emission areas in the supply chain process. Market demand and inventory movement can be predicted

and transportation can be minimized to reduce carbon footprint. Efficient transportation mode and route can be calculated (Hasan *et al.*, 2024).

In this research work we will study impact of nearshoring, ecofriendly packaging and technology on green business by reducing carbon footprint.

2 Research Questions

The study is being conducted to find answer to the following research questions.

1. Will Nearshoring, use of eco-friendly packaging and use of technology reduce the carbon footprint being emitted as part of supply chain?
2. What are the challenges to build a green business by optimizing supply chain?

3 Literature Review

3.1 Nearshoring to reduce carbon footprint emitted by supply chain

Longer supply chain where raw materials and finished goods are shipped from distant geagraphies contribute to poor air quality that has impacted the environment adversely. Primary causes of air pollution are greenhouse gas that gets emitted by distributors and manufacturers. Usually revenue and profitability take a lead while deciding the sourcing location but nearshoring can help reducing carbon footprint (Camacho-Vallejo *et al.*, 2023). Bringing down carbon footprint and defining a cap on carbon emissions can be done in Supplychain by optimizing transportation routes and use of green vehicles for transportation. Alternate nearshore locations, for example Mexico is a cheaper location near US and can mitigate supply chain cost when considering supply chain cost for businesses in US (Capar *et al.*, 2023). Using the international trade data and Environmentally Multiregional Extended Input Output (EMRIO) model it has been established that CO2 emmissions can come down with Nearshoring. The EMRIO model helps in calculating the carbon footprint considering the monetary value and involved in the whole process (López *et al.*, 2025).

Globalization facilitates businesses to procure raw materials and sell the goods across geographies. Eighty percent of globally traded goods follow the friendshoring approach where there is an agreement between friendly countries and businesses on trade exchanges. Friendshoring has risk of disruption of supplychain when there is a fallout in the trade agreements between the countries and businesses. Nearshoring and Reshoring can come to rescue here (Nedumpara, 2024). United States president Donald Trump has recently started a trade war across the globe that can cause significant disruption (York, 2025). Nearshoring or Reshoring can be a solution here. Nearshoring can also prevent damages of raw materials by shortening the supplychain and avaoiding damages due to transportation (Nagy *et al.*, 2025). Nearshoring helps in achieving efficient transportation route and minimizes risks and maximizes business value perceived (Smith, 2025).

3.2 Ecofriendly packaging in supply chain

Raw materials and finished goods are packaged while getting shipped. The packaging material has a significant impact on the environmental aspects and cost efficiency. Once the shipping is complete and the goods and raw materials are unpacked, the packaging materials are treated as waste and are disposed. Disposing of packaging material after unpacking causes carbon emissions. Sustainable packaging can help achieve the 4R (reuse-reduce-recycle-renew) thus reducing carbon footprint (Morashti *et al.*, 2022). The businesses have a huge focus on using sustainable packaging in supply chain to reduce carbon emissions (Stekelorum *et al.*, 2021). Sustainable nanomaterials are environment friendly and can reduce carbon footprint when used for packaging in supply chain. However, nanomaterials are expensive (Solomon *et al.*, 2024).

The waste management hierarchy as introduced to Euopean Union members can be used while dealing with packaging in the supply chain as below. Level 1 should be followed first and Level 5 should be followed if none of the other level suffices and should be avoided.

Level 1 – Prevention : Prevent using non-environment friendly packaging materials.

Level 2 – Reuse : Focus on Reusing the packaging materials.

Level 3 – Recycling : Recycle the waste and create new packaging.

Level 4 – Recovery : Generate energy from the packaging waste.

Level 5 – Disposal : Safely dispose the packaging waste.

Single use plastic should be avoided in packaging materials as per European Union directives. Biodegradable, fibre-based or reusable materials should be used for packaging. There are government regulations introduced by European Union Packaging and Packaging Waste Regulation (PPWR 94/62/EC) where sustainable packaging is a priority. However, sustainable packaging increases cost and consumer is more aligned to single use plastic that can be a challenge to use sustainable packaging (Ekanayake, 2024).

3.3 Use of technology in supply chain to reduce carbon footprint

Technology can help reduce carbon footprint in the supplychain. Sourcing decisions and consumer spending patterns impact supply chain. Artificial Intellgence and Big Data Analytics can help in identifying best sourcing locations, point of sale and optimized route to reduce carbon footprint. CO2 emissions can be measured and quantified by using technology (Naz *et al.*, 2022). Internet of Things based sensors can be used to track shipment routes and then use Artificial Intelligence to optimize shipment routes to reduce carbon emissions (Nahr *et al.*, 2021). Blockchain technology can reduce paperworks during supplychain and can safely store the information for access during shipment enabling secured supplychain tracking and analytics (Mubarik *et al.*, 2021).

3.4 Summary of literature review

From the literature review it is evident that Nearshoring, ecofriendly packaging materials and technology can help reduce carbon emission. Literature Review can be summarized as following.

- It is evident that nearshoring can reduce carbon footprint (Camacho-Vallejo *et al.*, 2023).
- Corporate governance practices like putting a cap on carbon emission during transporation of raw materials and finished products can promote nearshoring (Capar *et al.*, 2023).
- Models like EMRIO can help calculating carbon emissions (López *et al.*, 2025).
- Friendshoring is preferred approach over nearshoring most of the times. However, recent trade wars can promote nearshoring over friendshoring.
- Biodegradable, fibre-based and nanomaterials can be used for packaging materials (Ekanayake, 2024); (Solomon *et al.*, 2024).
- The waste-management hierarchy (Prevention-Reuse-Recycle-Recovery-Dispose) as introduced by European Union can be used while dealing with waste packaging materials (Ekanayake, 2024).
- There are government regulations in place in Europe that helps in using green packaging materials in supply chain (Ekanayake, 2024).
- Technologies like Blockchain, Big Data Analytics, Internet of Things (IoT) and Artificial Intelligence can be used to reduce carbon footprint in supplychain (Ekanayake, 2024); (Ekanayake, 2024).
- Cost efficiency can be a challenge while adopting Nearshoring and Ecofriendly packaging in supply chain (Morashti *et al.*, 2022); (Capar *et al.*, 2023).

- Consumer acceptance can be a challenge while adopting ecofriendly packaging (Morashti *et al.*, 2022).

It can be established from the existing literature that Carbon Footprint is the dependant variable. Nearshoring, ecofriendly packaging and technology can be independent variables. Green Practices is the mediating variable. Cost Sensitivity, Consumer Behavior and Regulations can be moderating variables. Figure 1 represents the relationship between these variables and the research model.

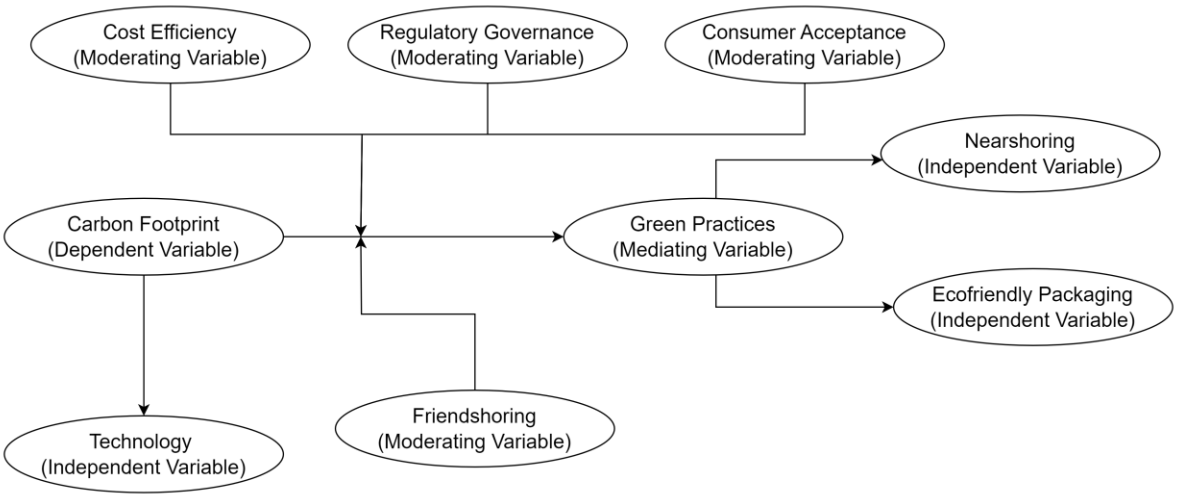

Figure 1. Research Model

4 Research Methodology

4.1 Research design

A quantitative cross-sectional study was performed to determine the relationship between the carbon emission that is the dependent varibale and sustainable supply chain practices that are independent variables along with the impact of friendshoring, cost and consumer acceptance that are moderating variables. A descriptive and explanatory approach was followed.

4.2 Sample population

The population for the research consisted of supply chain professionals, operations managers, green supply chain technology developers and sustainability practitioners from manufacturing, supplychain technology service providers and logistics firms. The sample population size was 54, identified using convenience sampling technique as the study was timeboxed.

4.3 Data collection method

Survey questionnaire with 5 point likert scale (Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree) and Yes/No questions was prepared using Google Forms. The research participants were shared with the Google Forms link and their responses were captured.

4.4 Data analysis

Descriptive statistics was performed on the responses provided to understand the relevance of nearshoring, ecofriendly packaging, use of technology and regulatory governance to minimize carbon footprint in supplychain. The collected data was analyzed using regression to study the impact of

moderating variables like friendshoring, cost and regulatory governance on reducing carbon footprint in supplychain process.

5 Results

5.1 Discussion of results

The research was conducted on 54 participants who are working in the supplychain domain and their responses were captured to validate the impact of nearshoring, ecofriendly packaging and use of technology to reduce carbon footprint. From the study it can be seen that 83 percent of participants have strongly agreed that nearshoring can reduce carbon footprint and 15 percent of the research participants have agreed to it. Figure 2 represents the results for impact of nearshoring on reducing carbon footprint in percentage.

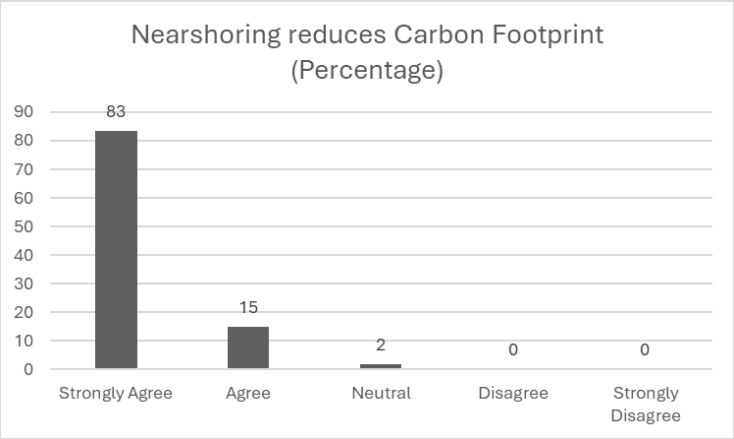

Figure 2. Nearshoring reduces carbon footprint

From the study it is evident that 83 percent of participants have strongly agreed that nearshoring can reduce carbon footprint and 17 percent of the research participants have agreed to it. Figure 3 represents the results for impact of ecofriendly packaging on reducing carbon footprint in percentage.

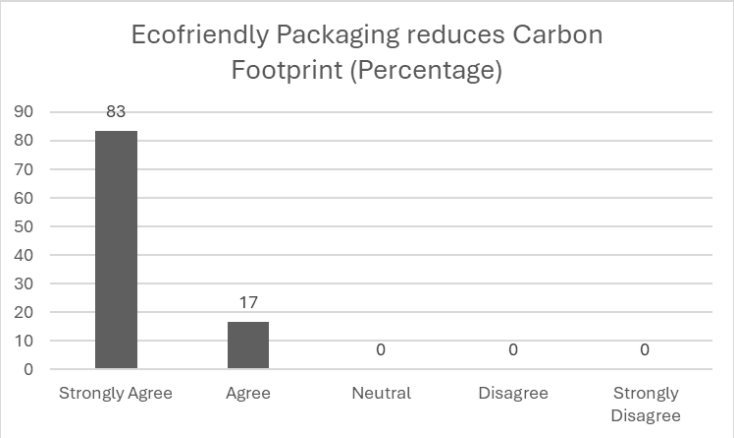

Figure 3. Ecofriendly packaging reduces carbon footprint

From the study it is evident that 74 percent of participants have strongly agreed that use of technology can reduce carbon footprint and 17 percent of the research participants have agreed to it. However a sizable 7 percentage of participants have preferred the neutral in their views and 2 percentage of

research participants have disagreed here. Figure 4 represents the results for impact of using technology on reducing carbon footprint in percentage.

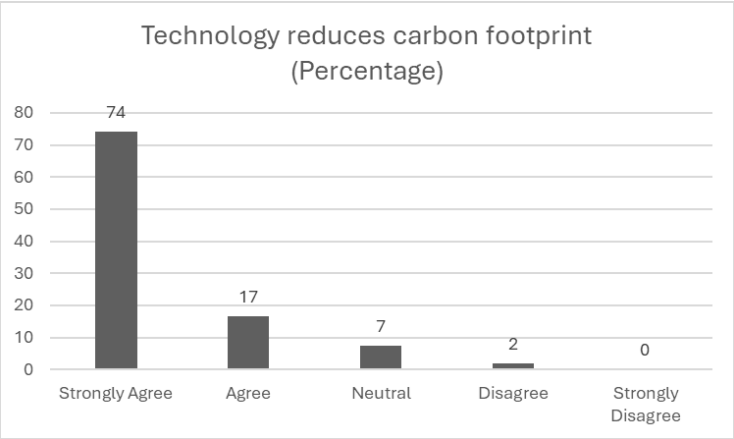

Figure 4. Technlogy reduces carbon footprint

From the study, it was evident that Regulatory Governance plays a major role in reducing carbon footprint. It helps in enforcing adoption of sustainable practices and moderates the adoption of green business processes. It can be seen that 96 percent of research participants have agreed that regulatory governance reduces carbon footprint and 4 percent of participants have agreed to it. Figure 5 represents the results for regulatory governance on reducing carbon footprint in percentage.

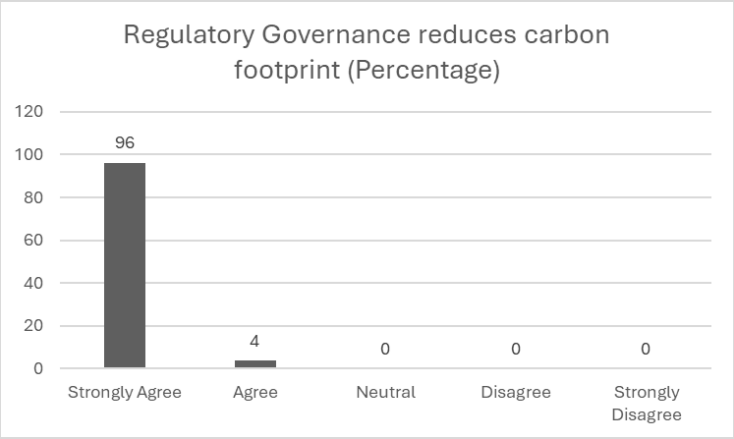

Figure 5. Regulatory Governance reduces carbon footprint

The participant responses based on Likert scale of 5 for nearshoring and regulatory governance was converted into numeric values as in Table 1. Increase in Regulatory Governance has direct relationship with nearshoring depicting that with increase in regulatory governance, increases adoption of nearshoring to minimize carbon footprint.

Likert Scale	Nearshoring	Regulatory Governance
Strongly Agree	5	5
Agree	4	4
Neutral	3	3
Disagree	2	2
Strongly Disagree	1	1

Table 1. Likert Scale conversion for Nearshoring and Regulatory Governance

The regression was performed with Nearshoring as dependent variable and Regulatory Governance as independent variable. At a confidence level of 5 percent or 0.05, it can be seen that regulatory governance has P-Vaule of 0.006 which is less than 0.05. Hence it can be established that with increase in regulatory governance, nearshoring increases and from descriptive statistics we have already established that nearshoring reduces carbon footprint.

	Coefficients	Standard Error	t-stat	P-Value
Intercept	0.45418	1.511938546	0.300396	0.765146286
Regulatory Governance	0.851159	0.298505369	2.851404	**0.006354249**

Table 2. Regression for Nearshoring and Regulatory Governance

The responses based on likert scale of 5 provided for ecofriendly packaging and cost of ecofriendly packaging was converted to numeric values and the regression was performed to validate if there exists any relationship between them. Table 3 denotes the likert scale data conversion making ecofriendly packaging and cost inversely proportional, denoting that more the cost, lesser is the adoption of ecofriendly packaging.

Likert Scale	Adoption of Ecofriendly Packaging	Cost increases with Ecofriendly Packaging
Strongly Agree	5	1
Agree	4	2
Neutral	3	3
Disagree	2	4
Strongly Disagree	1	5

Table 3. Likert Scale conversion for Ecofriendly packaging and cost

Table 4 denotes the result of the regression. Adoption of ecofriendly packaging is considered as independent variable and cost increases with ecofriendly packaging is considered as dependent variable. P-Value for regression for cost increases with ecofriendly packaging is 0.02 at a 0.05 or 5% confidence level. This illustrates that a clear relationship exists between adoption of ecofriendly packaging and cost increase with ecofriendly packaging and the relationship is inversional, depicting increase in cost of ecofriendly packaging, decreases adoption of ecofriendly packaging.

	Coefficients	Standard Error	t-stat	P-Value
Intercept	5.106719368	0.124560211	40.998	2.86162E-41
Increased Product Cost - Ecofriendly Packaging	-0.177865613	0.074488245	-2.388	**0.02061603935439**

Table 4. Regression for Ecofriendly packaging and cost

From the descriptive statistics, it is established that 56 percent of research participants strongly agree that ecofriendly packaging increases cost of the product and 35 percent have agreed to this. Figure 6 represents the participant responses for ecofriendly packaging increases cost of the product.

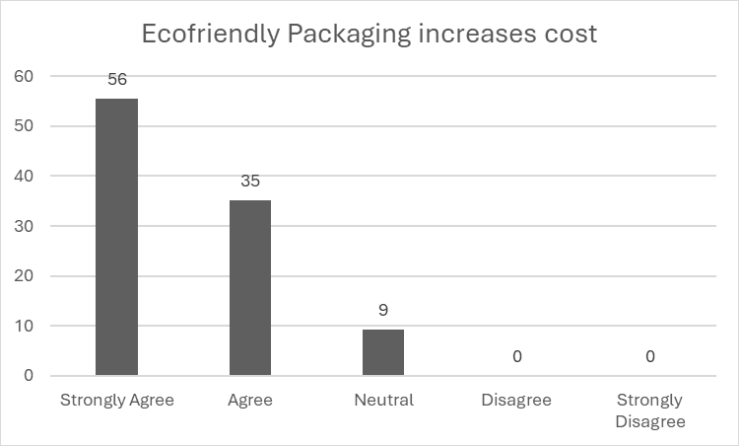

Figure 6. Ecofriendly packaging increases product cost

The participant responses based on Likert scale of 5 for nearshoring, friendshoring, increased product cost due to nearshoring, and regulatory governance was converted into numeric values as in Table 5. Increase in product cost due to nearshoring and friendshoring has inverse relationship with nearshoring depicting that with increase in cost due to nearshoring and increased adoption of friendshoring, reduces adoption of nearshoring to minimize carbon footprint.

Likert Scale	Nearshoring	Friendshoring	Increased Product cost due to Nearshoring
Strongly Agree	5	1	1
Agree	4	2	2
Neutral	3	3	3
Disagree	2	4	4
Strongly Disagree	1	5	5

Table 5. Likert scale conversion for Nearshoring, Friendshoring and Increased Product cost due to Nearshoring

The regression was performed with Nearshoring as dependent variable and Friendshoring and Increase in cost due to nearshoring as independent variables. At 0.05 or 5% confidence level, for Friendshoring and Increase in cost due to nearshoring, the P-Value is more than 5% or 0.05 confidence level. Friendshoring and increase in cost due to nearshoring has no relationship with Nearshoring and does not impact it. Table 6 denotes the regression results.

	Coefficients	Standard Error	t-stat	P-Value
Intercept	0.45418	1.511938546	0.300396	0.765146286
Friendshoring	0.118406	0.089531743	1.322507	0.192139213
Increased Product Cost – Nearshoring	-0.13026	0.104342642	-1.24841	0.217812647

Table 6. Regression for Nearshoring, Friendshoring, and Increased Product Cost - Nearshoring

5.2 Research question 1: will nearshoring, use of eco-friendly packaging and use of technology reduce the carbon footprint being emitted as part of supply chain?

It is evident from the descriptive analysis performed on the participant responses that Nearshoring, Use of Ecofriendly Packaging and Use of Technology minimizes carbon footprint. It was further confirmed from regression analysis that increase in regulatory governance increases adoption of nearshoring and hence reduces carbon footprint. It was also confirmed using descriptive analysis that increased adoption of regulatory governance minimizes carbon footprint.

5.3 Research question 2: what are the challenges to build a green business by optimizing supply chain?

From the results for data analysis it is evident that increase in cost for ecofriendly packages can impact adoption of using ecofriendly packages during the supply chain process. So increase in product cost can be a challenge in minimizing carbon footprint in supply chain process for a business. However, adoption of friendshoring and increase in cost due to nearshoring has no relationship with adoption of nearshoring practices as per the regression results.

6 Conclusion

In this paper the threefold approach comprising of Nearshoring, Ecofriendly Packaging and Use of Technology, to reduce carbon footprint in the supply chain process was studied. And it is evident by applying descriptive analysis to collected responses from participants that this threefold approach is effective. Nearshoring, Ecofriendly Packaging and Use of Technology helps reducing carbon footprint for supply chain operations. It was also evident that having regulatory governance in place can help adoption of this threefold approach and help reducing carbon footprint. From the regression analysis performed on the data, it can be seen that increase in cost for ecofriendly packaging impacts adoption of ecofriendly packaging in supply chain. So cost can be a challenge while adopting ecofriendly packaging. However Friendshoring and increase in cost does not impact adoption of nearshoring.

References

Camacho-Vallejo, J.-F., Dávila, D. and Nucamendi-Guillén, S. (2023) 'A hierarchized green supply chain with customer selection, routing, and nearshoring', *Computers & Industrial Engineering*, 178, p. 109151.

Capar, I. *et al.* (2023) 'Green Supply Chain Network Evolution: Modeling a Multimodal Logistics Strategy for Carbon and Cost Efficiency', *Available at SSRN 4572714* [Preprint].

Ekanayake, D. (2024) 'Sustainability in Finland's Fast Food Industry: challenges and opportunities in eco-friendly packaging solutions'.

Fernández-Miguel, A. *et al.* (2022) 'Disruption in resource-intensive supply chains: reshoring and nearshoring as strategies to enable them to become more resilient and sustainable', *Sustainability*, 14(17), p. 10909.

Ghosh, P., Jha, A. and Sharma, R. (2020) 'Managing carbon footprint for a sustainable supply chain: a systematic literature review', *Modern Supply Chain Research and Applications*, 2(3), pp. 123–141. Available at: https://doi.org/10.1108/MSCRA-06-2020-0016.

Hasan, M.R. *et al.* (2024) 'Integrating Artificial Intelligence and Predictive Analytics in Supply Chain Management to Minimize Carbon Footprint and Enhance Business Growth in the USA', *Journal of Business and Management Studies*, 6, pp. 195–212. Available at: https://doi.org/10.32996/jbms.2024.6.4.17.

López, L.-A. *et al.* (2025) 'Consequences of legislation-based reshoring for EU carbon emissions in global value chains', *Journal of International Business Policy*, pp. 1–21.

Morashti, J.A., An, Y. and Jang, H. (2022) 'A systematic literature review of sustainable packaging in supply chain management', *Sustainability*, 14(9), p. 4921.

Mubarik, M. *et al.* (2021) 'Impact of blockchain technology on green supply chain practices: evidence from emerging economy', *Management of Environmental Quality: An International Journal*, 32(5), pp. 1023–1039.

Nagy, H. *et al.* (2025) 'Sustainability in the commercial sector–the international trend of the shorter supply chains', *Marine Development*, 3(1), p. 8.

Nahr, J.G., Nozari, H. and Sadeghi, M.E. (2021) 'Green supply chain based on artificial intelligence of things (AIoT)', *International Journal of Innovation in Management, Economics and Social Sciences*, 1(2), pp. 56–63.

Naz, F. *et al.* (2022) 'Reviewing the applications of artificial intelligence in sustainable supply chains: Exploring research propositions for future directions', *Business Strategy and the Environment*, 31(5), pp. 2400–2423.

Nedumpara, J.J. (2024) 'Editorial: Friendshoring, Nearshoring, Greenshoring and Resshoring: Changing Faces of Global Supply Chains and its Impact on International Economic Law - Introduction to the Special Issue', *Global Trade and Customs Journal*, pp. 125–128.

Silva, N. and Molina-Besch, K. (2023) 'Replacing plastic with corrugated cardboard: A carbon footprint analysis of disposable packaging in a B2B global supply chain—A case study', *Resources, Conservation and Recycling*, 191, p. 106871. Available at: https://doi.org/10.1016/j.resconrec.2023.106871.

Smith, A.D. (2025) 'Nearshoring and its potential impacts on the global supply chain: case study of retailing and manufacturing firms', *International Journal of Business Forecasting and Marketing Intelligence*, 10(1), pp. 1–21.

Solomon, N.O. *et al.* (2024) 'Sustainable nanomaterials' role in green supply chains and environmental sustainability', *Engineering Science & Technology Journal*, 5(5), pp. 1678–1694.

Stekelorum, R. *et al.* (2021) 'Green supply chain management practices and third-party logistics providers' performances: A fuzzy-set approach', *International Journal of Production Economics*, 235, p. 108093.

York, E. (2025) 'Trump tariffs: The economic impact of the trump trade war'.