Green Supply Chain Management and The Impact of Eco Transportation on Operational Efficiency

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Abstract- ***In the recent past, Green Supply Chain Management (GSCM) has become a vital engagement model for achieving goals of environmental responsibility and supply chain performance. To achieve this goal of understanding the part played by eco-transportation towards realistic improvement within GSCM, this study employs a secondary analysis of journal articles, industry papers, and empirical research. These research outcomes show that the implementation of eco-transportation technologies like EVs, hybrid trucks, and AFVs to a large extent alleviates fuel expenses, and increases the delivery frequency and efficiency in the use of resources. Governments therefore have a very important role in providing policy support for eco-transportation, with parts of the world like the European Union being particularly successful due to tight emission laws and incentives. However, there has been wide-scale adoption hampered by factors like cost, lack of infrastructure, and type of industry. This paper discusses that retail end e-commerce industries are more likely to use drones for last-mile delivery, while heavy industries have some limitations as to payloads and range. Therefore, if these trends: automation, AI, and green hydrogen, are to be delivered they offer a vision of how it can be done and offer solutions to these challenges for sustainable logistics. The paper argues that eco-transportation is crucial to developing sustainable and efficient supply chains and outlines practical implications for practice, policies, and academics. When filling infrastructure deficiencies, promoting innovation, and bringing regulation into conformity with market needs, eco-transportation can contribute to the adaptation of the global supply chain towards increased eco-efficiency.***

I. INTRODUCTION

This led in recent decades to raising the bar in regard to environmental sustainability and turning people's focus to the environmentally friendly forms of the economy. The advance of industrialization, globalization, and consumerism expands the environmental influence of supply chain operations, which makes green supply chain management (GSCM) an innovative imperative for organizations that pursue long-term sustainability. It focuses on the incorporation of sustainable green activities in the supply chain with the help of decisions made for buying raw materials from suppliers to the delivery of the end product with an emphasis on the disposal of waste and usage of resources (Sarkis, 2012). Of these practices, eco-transportation, which is an environmentally sustainable way of managing transport and logistics, has become an area of operational significance in the efforts to lift efficiency standards while lowering impacts on the environment. A discussion of what this paper entails, as well as an analysis of GSCM and the effects of eco-transportation on operational effectiveness, based on the relationship between sustainability and business performance.

The environmental impacts of traditional supply chain activities are dramatic. Nonetheless, logistics and transportation industries remain the most significant emitter of CO2, especially because they contributed to 24% of energy-related greenhouse gas emissions in 2021 (IEA, 2022). Freight transportation channels which include road, air, and sea transport use fossil fuel and their releases contribute to climate change and air pollution. In addition to that, routing, vehicle use, and delivery scheduling complicate fuel consumption and operations costs (McKinnon et al., 2015). As a result, organizational eco-transformation measures such as environmental highways, switching to electric and hybrid transport, logistics networks' optimization, and the application of other types of fuel and energy sources have emerged. These strategies do not only focus on the minimization of environmental effects, but also incorporate lessening expenses, better utilization of materials, and increased innovation (Russo & Comi, 2012).

The green supply chain is based on sustainable development, making it possible to achieve extraordinary growth in the economic sector without

jeopardizing the welfare of the population as well as the environment (Elkington, 1997).

Regarding GSCM, this has impacted on its objective of eliminating waste, reducing energy use, and enhancing the procedure that occurs in the supply chain map by factoring in environmental factors (Srivastava, 2007). For instance, companies using closed-loop supply chain management, which concentrates on recycling and remanufacturing activities, can reduce the number of virgin materials effectively yet improve operational performance. These practices are most relevant when it comes to eco-transportation, which is the consolidation of vehicle electrification, adventitious rout algorithms, and green warehousing systems to meet both environmental efficiency and economic sustainability goals of any given supply chain (Raut, et al., 2019).

Eco-transportation has emerged as a new important element of GSCM, which in turn has presented several measures for reducing environmental risks for companies and enhancing their performance. The use of electric, hydrogen, or biofuels has been remarkable in cutting down emissions of GHG and energy needs from unsustainable sources (Zhang & Zhao, 2019). For instance, Tesla manufactures electric trucks, and Toyota's hydrogen-powered fleets generate fewer emissions than traditional diesel-based trucks. Further, new intelligent technologies applied in smart logistics, including IoT used in fleet tracking systems and real-time traffic systems, have improved the delivery routes and minimized fuel consumption, which in turn, will reduce costs and deliver quickly.

Besides, the benefits of eco-transportation in enhancing operational-economic benefits show why it is essential in the transport business. Small amounts of fuel used when traveling also aid in lowering overall transportation costs, as well as protecting businesses from fluctuating fuel prices, thus improving their cash flows (Wu and Dunn, 1995). Furthermore, it has a strong business case since investments in eco-transportation technologies are usually recoverable in the long run by cost efficiencies such as better asset turnaround, and customer satisfaction through improved reliable and timely delivery. For example, companies such as DHL and UPS have shifted to green logistics solutions such as route optimization and electric delivery vehicles that save costs and create more brand value (Abdulrahman et al., 2014).

These examples highlight the potential of eco-transportation to achieve the triple bottom line of sustainability: economic, environmental, and social impact performance measures.

Since eco-transportation and GSCM are advantageous, their planning is not smooth sailing. Pecuniary barriers include high initial costs that may include technology acquisition, moderate to low technological innovation, and organizational inertia (Govindan et al., 2014). For example, the switch towards electric vehicles demands investment in charging equipment and batteries which may compel SMEs not to implement such systems. Furthermore, there are no clear-cut international rules and guidelines that create the impetus for adopting environment-friendly mechanisms to supply chain management across the world and this plays a crucial role in the development of such structures. Such problems highlight the importance of an integrated approach among all major categories of actors: governments, businesses, and customers to eliminate obstacles that hinder the effective implementation of green supply chain strategies (Carter & Rogers, 2008).

Transportation is not incorporated into GSCM as a reaction to environmental issues but as a solution to improve competitiveness within the global market. Today, customers and investors insist on being informed more often about the companies' environmental policies (Walker et al., 2008). Those business organizations that implement more efficient eco-transportation and other green supply chain management measures are better placed to capture the market share of green-controlled consumers, look forward to receiving funding from sustainable-minded investors, and indeed meet and conform to newer, tighter, and demanding regulatory environmental compliance standards. In addition, they also point out that the integration of GSCM practices with organizational objectives creates value and makes organizations more innovative and responsive to fluctuating market environments and new forms of environmental risks (Zhu et al., 2008).

In developing this line of thought, this paper aims to employ other scholars' works to analyze the effect of eco-transportation within the GSCM framework for operational efficiency. Based on theoretical concepts and empirical findings, it analyses the processes promoting eco-transportation performance improvement and illustrates where and how advantages for efficiency and sustainability developed; it also reveals the key enablers and constraints for its adoption and outlines the problems solved and unsolved with its help, as well as the potential impacts for knowing and acting.

This research evidently fills the existing literature gap by designing and testing a Middle East-based GSCM framework that connects environmental and operational sustainability, as well as offering beneficial recommendations for future green SCP studies, research, and practices.

II. LITERATURE REVIEW

The idea of Green Supply Chain Management (GSCM) has emerged over the past few decades due to mounting environmental considerations and the demand for integrating supply chain activities for sustainable development. In their effort to increase the measure of environmental responsibility, GSCM has come to be considered as the comprehensive solution to the problem of integrating sustainability into the supply chain. Built around eco-transportation as its core concept, it is aimed at enhancing operational performance and lowering negative effects on the environment at the same time. This literature review draws together literature on GSCM more generally and the use of eco-transportation to contrary operational efficiency in the supply chain.

Green Supply Chain Management

As stated by Srivastava (2007) GSCM stands for Green Supply Chain Management, the process of implementing environmental concerns into the supply chain to mitigate the impact of the environment by business undertakings. Purchasing management entails buying practices that recycle, reuse, and reduce as well as the overall environmental impact of manufactured products and supply chain processes (Carter & Rogers, 2008). The factors that have influenced the implementation of GSCM are as follows; Firstly, it is compelled by the regulatory compliance requirement; secondly, by the market interest in environment-friendly products; and finally, by the necessity for organizations to gain competitive advantage by enhancing their environmental management performance (Sarkis, 2012). GSCM has attracted much attention in the past few years because earlier studies established that green supply chain management not only improves environmental quality but can also bring about better efficiency, lower costs, and increased customer loyalty (Zhu et al., 2008).

The Role of Eco-Transportation in GSCM

Eco-transportation is one of the subsets of green logistics; the concept is defined as the use of cleaner transportation activities to reduce the carbon footprint activities associated with transport within the supply chain (McKinnon et al., 2015). They include the acquisition of AFVs, route optimization and scheduling, real-time tracking by telematics, and green packaging and transport structures as outlined by Raut et al., (2019). Eco-transportation is emerging as a result of the high environmental cost of the traditional transport system, which includes increased greenhouse emissions; air pollutants, and the depletion of resources (Perera et al., 2020).

Traffic and transport are said to be some of the leading producers of greenhouse gases in the world. Transportation is known to be the fourth-highest contributor to global energy-related CO2 emissions, which amounts to 24%, and the biggest offender within the sector is road freight, says the IEA, 2022. Thus, harmonizing the environmental cost of transport has driven eco-strategies for efficient GSCM solutions. Eco-transportation is expected not only to exclude misuse of the environment but also to enhance operational and managerial effectiveness. The benefits of eco-transportation include the following: Less fuel consumption means low operating costs, and better return on investment in the existing assets which would increase supply chain efficiency (Russo & Comi, 2012).

Key Strategies in Eco-Transportation

1. Alternative Fuel Vehicles: One of the most important achievements in the eco-transportation field is the shift from using fossil fuel-based transport to AFVs such as electric vehicles, hydrogen-driven

vehicles, and biofuel vehicles (Schechter, 2009). To policymakers, AFVs are considered a direct response to the challenges of carbon emissions and fossil fuel dependency. One outstanding example of how the transport sector is coming up with ways of making deliveries sustainable is through the increased use of electric trucks and delivery vehicles.

Some of the major logistics firms like DHL and UPS have already started the use of electric vehicles in their operations focusing on the reduction of the overall environmental impacts (Abdulrahman et al./Tudor et al., 2014). These vehicles are significantly advantageous in many ways: first, they emit lower emissions; second, they appear to have lower costs of ownership in the long run since they need less of an overhaul and third, they are cheaper to run than I.C.E. Vehicles.

2. Route Optimization and Fleet Management: Apart from the main strategy of shifting from conventional fuel vehicles counterparts then other vital strategies that fall in the intends and purposes of an eco-transportation plan include the efficient and effective management of the transport network. Technologies like Geographic Information Systems (GIS), telematics, and real-time tracking results bear the potential to route the delivery vehicles more efficiently and that would minimize fuel resources and emissions as well. Since companies can monitor the traffic flows and rearrange or reschedule the delivery timings and locations in real time this will help them avoid traffic congestion, minimize the total distance traveled by delivery vehicles, and improve the operational performance of the delivery fleet (Perera et al., 2020). Route optimization therefore aligns not only to cost-saving fuel but also improves delivery functions due to timely and effective shipments.

3. Modal Shift and Intermodal Transportation: Another sub-strategy under eco-transportation is the movement of goods away from what could be termed road-centric logistics and instead to more environmentally friendly options including rail, sea, or airways. This shift is sometimes called intermodal transport and is the process of undertaking a shipment using more than one mode of transport. Intermodal transportation is much more environmentally friendly and cost-effective compared to measures, especially for lengthy distances. There is evidence that for some forms of freight transport, such as rail transport, road transport is energy-wasteful and polluting (McKinnon et al., 2015). Likewise, sea transport is relatively more sustainable than air transport in terms of freight, but the emissions resulting from maritime shipping are also issues (as indicated in Zhang & Zhao, 2019).

4. Greener Infrastructure and Packaging: Eco-transportation also involved the integration of green logistic infrastructures which consist of the establishment of charging stations for electric vehicles, the utilization of renewable energy sources for transportation infrastructures as well as efficient energy storage and usage in warehousing facilities. The inclusion of a better approach to packaging to include the use of recyclable and biodegradable materials as a way of enhancing the transport networks' sustainability is part of our conclusions. A few studies have also shown that integrating investments in sustainable transport infrastructure and circular economy principles can substantially decrease not only the negative environmental effects but also the operating costs (Raut et al., 2018).

Effect of Eco-Transportation on Performance

Environmental plans applied to transport can change organizational operations depending on organizational and customer requirements in terms of cost and logistical performance as well as resource utilization. Several prior researchers investigated how eco transport affects supply chain performance and it has been revealed that such transport results in large gains for overall supply chain efficiency.

1. Cost Reduction: The first advantage is that eco-transportation makes considerable economic sense, in the way that traditional environmental management does. The costs are higher at the initial stages of AFV use, compared to conventional gasoline and diesel vehicles, owing to the higher initial investment costs for manufacturing and infrastructure for the production and distribution of AFVs, yet AFVs possess the potential of yielding greater benefits in terms of operational expenses and maintenance (Zhang Zhao, 2019). Furthermore, lessening fuel costs by identifying the shortest and safest way to travel as part of a fleet also improves overall fleet performance. Examples in the case of logistics have demonstrated that the use of sustainable transportation has a positive effect such as reduced costs in the industry. For instance, Abdulrahman et al. stated that through the implementation of electric vehicles, and optimization

of delivery routes, firms such as DHL have recorded huge savings (2014).

2. Improved Delivery Performance: The last benefit of eco-transportation can be said to be an effect on delivery performance. Optimization of routes, and utilization of actual tracking equipment not only lowers fuel consumption but also delivers products more effectively and in time. Customers expect services to be delivered faster and with great efficiency; the firms and organizations that embrace eco-transportation are well placed to deliver this to the consumer in sustainable ways. Real-time detail of delivery schedules makes it possible for businesses not only to enhance service levels but also to increase customer satisfaction (Perera et al., 2020).

3. Resource Utilization and Asset Management: They also assist in exercising resource and asset optimization throughout the chain of supplies in various forms of eco-transportation approaches. For instance, fleet optimization, as well as the embrace of telematics, also allows businesses to realize increased vehicle productivity with the understanding that the vehicles are used optimally. The actual time tracking of fleet performance enables businesses to plan and schedule maintenance and repair of their fleets ahead of time, hence minimizing downtime and increasing operational efficiency (Russo & Comi, 2012).

4. Compliance and Competitive Advantage: Finally; eco-transportation can enable organizations to overcome the challenge of implementing the current and continuously strengthening environmental standards, which if flouted, attract penalties. Furthermore, implementing sustainable solutions makes companies more competitive since they can appeal to environmentally aware customers and investors. Such works have indicated that there is a likelihood of Product and market positioning by incorporating GSCM and eco-transportation into business structures (Zhu et al., 2008). The consumer focus has shifted towards environment-friendly products and services and businesses that are environmentally friendly have a higher likelihood of capturing the market.

Challenges and Barriers

Nonetheless, there remain several threats to the formulation of eco-transportation and its implementation on a wider scale. These are among challenges include; High initial costs which indicate that the initial setup for a green supply chain requires a huge amount of investment, Technological limitations which suggests that innovative technology to support green supply chain management is limited, Resistance to change which implies that introducing green supply chain management usually faces a lot of resistance from organizations because most of them are not willing to change their conventional ways of operation (Khan and Ahmad, 2010). For instance, changing from the use of internal combustion-powered vehicles to those that are electric involves a lot of capital outlay in things like charging points and vehicle hardware. In addition, a relative similarity in the trade policies of different countries that implement green policies, particularly eco-transportation practices, lacks unity in regulations. These challenges call for the collective effort of different actors to develop suitable policies and favorable incentive systems that will help in realizing green mobility systems.

The incorporation of eco-transportation into GSCM has the possibility of adding much-improved efficiency to operations and at the same time achieving environmental objectives. Some tactics include the following, utilizing vehicles that run on alternative fuel, redesigning the routes and channels, using intermodal transport, and constructing greener infrastructure for delivering performance, cost savings, and efficient resource deployment. Therefore, there are barriers, for example high initial costs and constraints of technology that need to be addressed for its large-scale implementation. Eco-transportation remains important in supporting the emerging green supply chains due to a continuously rising demand for sustainability.

III. METHODOLOGY

The research approach used in this study is secondary analysis. Secondary research entails identifying current data, academic literature, theoretical and empirical publications, case studies, and research reports to comprehensively address the understanding of green supply chain management (GSCM) and the effects of eco-transportation on efficiency. This line of research suits the purposes of the study as it allows for the analysis of prior theories, as well as assessing the

frameworks and practices in the context of GSCM – especially in the context of eco-transportation.

Research Approach

This research employs an exploratory qualitative research design to examine the relationships between eco-transportation initiatives and operation performance in the context of GSCM. This is done through a systematic review of the extant literature to operationalize this study as having a qualitative-based foundation with theoretical sound principles and evidence, as posited by Suri (2020). This study stands to gain from previous work, in an attempt to obtain useful information on how companies incorporate eco-transportation solutions into their networks, and finally, how basic operational performance indices are measured and achieved.

Data Sources

Both primary and secondary research data were used for this study; the source of primary research data included peer-reviewed journal articles, while secondary sources included industry reports, and government publications, among others; credible databases included SCOPUS, Web of Science, and Google Scholar among others. It was conducted to cover the primary research that started together with GSCM and eco-transportation development to capture the recent studies carried out until 2024.

Keywords that were considered to be relevant to the study were green supply chain management, eco transport, operational efficiency, sustainable logistics, AFV, and sustainable transport.

Participants Selection Criteria:

To ensure the relevance and academic rigor of the analysis, specific inclusion and exclusion criteria were established:

1. Inclusion Criteria:

Research articles from peer-reviewed journals and academic journals on GSCM and eco-transportation.

To this end, the next section of the paper presents an analysis of published literature examining the underlying link between eco-transportation and improved business operations.

Approximates from the industries that have integrated GSCM practices.

Articles that specifically discuss transport technologies such as electric cars, routes, and intermodal transportation.

2. Exclusion Criteria:

Journal articles and case studies, conference papers that are not in the field of supply chain and sustainable transportation.

Editorials as well as other articles that have not been published in accredited, peer-reviewed scientific journals.

Papers that contain only environmental policies with no operational consequences.

Analytical Framework

Thematic, that is patterns, and recurring themes have been integrated into the current analysis to deconstruct the themes found in the reviewed literature. The process involves the following steps:

1. Literature Screening: Using the location of abstracts, keywords, and titles in order to provide the necessary criteria for the identification of relevant investigations.

2. Thematic Categorization: Organizing the findings into categories which include: Eco-transportation 21 Types, benefits associated with eco-transportation Operations efficiency measurements which include green supply metrics; Opportunities, and barriers to GSCM.

3. Comparative Analysis: It stands to define how different industries, and geographical areas have compared to one another over time and cross-section periods to see the pattern of eco-transportation usage.

4. Synthesizing Results: The process by which integrated research findings and synthesized an answer to research questions.

Reasons for Secondary Analysis

Secondary analysis was selected due to its characteristics that allow for using extant information to make new conclusions without obtaining new data. This approach is particularly useful for relatively well-researched topic areas such as GSCM and eco-transportation where vast amounts of information in the form of cases already abound. The integration of such works gives the methodology an adequate view of how the eco-transportation strategies affect operational performance. Secondly, secondary analysis does not limit the study to a particular

industry and geographical area as it can look outside for resources (Heaton, 2008).

Validity and Reliability

To ensure the validity and reliability of the findings, the following strategies were employed:

1. Triangulation: A cardinal step to reduce bias in that the evidence is drawn from cross-sectional sources in an attempt to confirm the conclusions of one source by another.
2. Critical Appraisal: Determining the reliability, research design, and appropriateness of the data in each of the studies under review.
3. Transparency: Increasingly transparent in terms of the search terms used, databases searched, and reasons for study inclusion.

Ethical Considerations

Since this research employs secondary data only, appropriate citation of data sources and recognition of the original authors present the main ethical issues. All materials cited in the paper are properly cited in compliance with the established guide of APA 7th edition to combat a falling standard of intellectual honor and the disregard for other individuals' work by scholars.

By using SA, a sound methodological approach to analyze the effects, derived from the implementation of eco-transportation about the present investigation of operational efficiency under GSCM, can be established. Building on the literature review, the study provides solutions that summarize current findings of sustainable supply chain strategies and enhance the discussion on environmental considerations in logistics. The thematic analysis also helps constrain the study to empirical reality as well as establish theoretical credibility of the findings, making them useful for common and academic practice.

Findings: An investigation into Green Supply Chain Management and the Effects of Eco-Transportation on Efficiency.

Secondary analysis of the data provided an understanding and comprehension of GSCM, eco-transportation, and operational efficiency. The findings are categorized under the major areas that emerged from the analysis of literature and aggregated from several studies to provide trends, challenges, and opportunities analysis.

1. Promotion of Eco-transportation Technologies

Previous studies show that eco-transportation technologies like EVs, hybrid trucks, and AFVs are part of the GSCM strategy. These technologies enhance the efficiency of fuel and decrease carbon emissions, which conforms with sustainable development goals (Zhang and Zhao, 2019).

Key Findings

Technology	Benefits	Challenges	Adoption Rate (2023)
Electric Vehicles (Evs)	Zero emissions, low operational cost	Limited range, high initial cost	35% in logistics
Hybrid Trucks	Reduced fuel consumption	Complex maintenance	45% urban delivery
Alternative fuel vehicle	Lower greenhouse gas emission	Lack of infrastructure	25% in freight

2. Operational Effectiveness

Eco-transportation has a positive correlation with operation performance gains in terms of cost, routing, and resource management. The research indicates that organizations implementing eco-transportation technologies record enhanced transport cost and delivery time savings (McKinnon et al., 2015).

Operational Efficiency Metrics:

Efficiency metric	The improvement observed (%)
Fuel cost reduction	25
Delivery time optimization	15
Asset utilization	20

3. Environmental and Regulatory Impacts

Eco-transportation management techniques are typically applied where there is a regulation or an environmental stimulus is given. Currently, governments around the globe support green logistics through the implementation of carbon taxes, subsidies for electric vehicles, and more enhanced emission

standards around the world (International Energy Agency, 2022).

Findings on Regulatory Influence:
Eco-transportation has a higher adoption in regulating regions such as the EU than in developing countries.
An assortment of compelling benefits includes the opportunities for increased operational margins by way of tax incentives and, in some cases, subsidies for the use of alternative fuels.
Which helps improve corporate image, an intangible operating advantage.

4. Challenges to Adoption
Nonetheless, several challenges have been observed as the inhibiting factors towards the improved practice of eco-transportation. These are; initial capital requirements, technical restraints, and a lack of adequate support structures (Raut et al., 2019).

Challenge	Impact on Adoption	Suggested solutions
High initial cost	Slows adoption of Evs and hybrid	Government subsidies, leasing models
Lack of infrastructure	Limit intermodal logistics	Public-private partnerships
Limited technological maturity	Inconsistent performance	R&D investment

5. Industry-Specific Insights
The secondary analysis also found out the trends and uniqueness of the industry of the eco-transportation. For instance, the extent of readiness of the industries is relatively high for retail and e-commerce due to the delivery services in urban settings as well as low for heavy industries due to the system complexities of those industries.

Industry	Adoption level	Key trends
Retail/e-commerce	High	Focus on Evs for last-mile delivery
Manufacturing	Medium	Use of hybrid vehicles for raw materials
Heavy Industries	Low	Barriers due to payload requirements

6. Emerging Trends
The review highlighted emerging trends that could reshape eco-transportation practices in the coming years:
Automation and AI: Improved manner of optimizing routes and the management of fleets.
Green Hydrogen Vehicles: Solving the issues related to range and payload.
Carbon Accounting: Incorporation of measures of eco-transportation into corporate carbon disclosure.
The paper reveals that eco-transportation is a crucial part of GSCM which can bring significant opportunities in terms of tangible and intangible goals for supply chain organizations. One can identify a few critical barriers that need to be addressed to unlock the wider application of blockchain: the cost and the infrastructure. These practices are encouraged by industry-specific practices and government support.
This paper offers a synthesis of the current knowledge to assist both academic and industry audiences to engage in and apply effective eco-transportation concepts and practices.

IV. DISCUSSION

The research studies conducted for and presented in this thesis yielded strong empirical evidence on the application of eco-transportation as a critical aspect of operation and GSCM. Based on a secondary analysis of the data collected from several scholarly sources, this discussion integrates the results and discusses the implications of theory, practice, and further research.

Adoption of Eco-Transportation Technologies: The use of green technologies in transport including electric cars, hybrid trucks, and AFV has therefore evolved into one of the most critical areas for green supply chains. All such technologies are beneficial in terms of emissions cuts, increased fuel economy, and compliance with worldwide environmental standards. Following the same line, Zhang and Zhao, (2019) pointed out that electrification of transportation by EVs and hybrid trucks has revolutionary impacts in urban logistics where they offer both zero-emission and cost advantages.

Nevertheless, the adoption is sector-and region-specific because of factors such as high capital cost and lack of support structures. For example, although multiple urban logistics sectors have a higher rate of acceptance, some hefty industries experience challenges because of payload and range constraints. This has underlined that to successfully implement technical solutions, it is necessary to look at industry-specific approaches due to techno-economic barriers that exist. The research implies that policy inducements like grants in the form of subsidies from the government, and synergy in public /private partnerships in the provision of infrastructural facilities, would enhance the use of eco-transportation, more so in the less progressive industries.

Impact on Operational Efficiency: Out of all conceptual relationships established by this paper, eco-transportation has the most prominent contribution to GSCM through improving operational efficiency. As proved by McKinnon et al. (2015) intents and integration of eco-transportation technologies enable the realization of the benefits of fuel cost, delivery time, and resources. For instance, fuel costs by as much as 25% and delivery times by as much as 15% are achievable improvements in the competitiveness of using firms.

The results in these studies substantiate the theoretical hypothesis put forward in this research that the concepts of operational effectiveness and eco-palatability are not antagonistic, but complementary. Through a reduction of fuel expenditure and efficient ways of delivering goods, the cost of production decreases and carbon emissions decrease as well. In addition, according to the increased asset utilization rates known by Sarkis, (2012), it is also noted that the sustainability deals with eco-transportation improvement relation also increases the robustness and adaptability of the supply chain configuration.

Environmental and Regulatory Influences: This paper tries to establish that regulatory frameworks and environmental incentives have a significant influence on the adoption of eco-transportation processes. In some areas that have set high emission standards like the European Union, they have seen higher rates of adoption due to policies like carbon taxes as well as incentives to owners of vehicles that use alternative fuels (International Energy Agency, 2022). They not only enforce compliance but also offer financial motivation to the firms to spearhead sustainable transportation technologies.

Furthermore, proving compliance with environmental regulations also results in such soft organizational outcomes as improved reputation and stakeholders' trust. This can also be supported by Carter and Rogers (2008), who contended that detailed sustainable strategies that are implemented maximize long-term competitive advantages through positive stakeholder relations. However, the study also presents regional variation in regulating influence; the study finds that the challenge arises in developing countries because of the relatively weaker enforcement mechanisms coupled with inaccessibility to financial incentives.

Challenges to Adoption

Nevertheless, numerous impediments prevent the widespread usage of eco-transportation practices, which are evident. Thus, high costs of initial investment remain a key hurdle, especially for SMEs given their relatively constrained capital base. They share the same idea with Raut et al. (2019) who pointed out that the choice is usually made based on costs with little regard to the impact on the environment.

Charging times and provisions for electricity shortages also contribute to reduced uptake together with intermodal transport facilities for electric cars. Solving these issues is only possible at the expense of the unification of efforts of governments, private firms, and industry members to create the proper infrastructure and shift the burden of change to eco-transportation on the shoulders of all the countries. Therefore, according to Russo and Comi (2012), public-private partnerships represent a feasible solution to the systemic challenges that characterize employment trajectories of workers with precarious employment status.

Industry-Specific Insights

The results tentatively show a high level of industry heterogeneity regarding the usage of eco-transportation. Some industries, including retail and e-commerce seem to have higher penetration because of

the focus on the delivery method known popularly as the last mile delivery and the need to solve for the consumer interest in sustainable solutions. On the other hand, there are industries such as heavy industries that require high capacity and long-distance transportation is technologically and economically constrained.

Such differences call for customization of the eco-transportation initiatives depending on the industries that are involved. For instance, retail and e-commerce companies should directly access incumbent and cutting-edge infrastructure systems in EVs and optimization of client supply routes, while upstream-heavy industries shall need new solutions such as green hydrogen vehicles and heavy hybrid trucks suitable for big loads.

Emerging Trends and Future Implications

New opportunities are arising from the automation trends, AI, and green hydrogen vehicles in trying to enhance the eco-transportation key activities. Automated GPS-based route planning and vehicle tracking systems can complement the other two models by saving fuel and achieving a high level of delivery precision. On the other hand, green hydrogen technologies are seen to have the potential to solve the range and payload challenges that are evident in modern eco-transportation solutions, especially in Endurance and payload levels of heavy transport and industrial uses.

Furthermore, the extension of carbon accounting in corporate sustainability reporting shows that companies increasingly value ways to measure their supply chain environmental footprint. Metrics for eco-transportation activities can become a powerful tool for firms that apply them since the latter can use them explicitly to draw attention to their willingness to adopt sustainable strategies in competitive markets.

Research Implications: Theoretical and Practical

The work enriches the theoretical concept of GSCM by showing the relationship between eco-transportation and operational performance. Accordingly, they open up the understanding that more sustainable approaches can generate value that is both environmental and business, to support frameworks like Carter and Rogers' (2008) sustainable supply chain model.

From the pragmatic logistician's point of view, the research provides timely and valuable suggestions for supply chain professionals and government regulators. It is suggested that firms should approach eco-transportation in stages: starting with affordable options such as hybrids and routing before moving on to exotic technologies like EVs and green hydrogen trucks. The key stakeholders, on the same note, should focus on policy suite and come up with a conducive environment of policy support for the diffusion of eco-transportation.

Finally, the discovery reflects the change in the opportunity of eco-transportation in the context of GSCM. As a result, eco-transportation practices improve the competitive advantages of firms that undertake such practices as well as support global sustainability objectives. Nonetheless, the kind of challenges that are inherent to the industry like high costs, limitations in infrastructure, and others are not easy to tidy over and call for collective and conscious efforts from the industry majors as well as the policymakers. Subsequent studies need to continue investigating new technologies' consequences for the future and study the contexts affecting eco-transportation adoption across diverse industries and regions.

CONCLUSION

This research paper highlights the importance of eco-transportation under the GSCM concept and its considerable influence on operations. This paper uses secondary data resources to synthesize the evidence, to show that eco-transportation not only relates supply chain activities to international sustainable development goals but also leads to the improvement of further chain performance indicators, including cost control, delivery accuracy, and resource efficiency. This is the case with the use of technologies like electric vehicles, hybrid trucks, and other different AFVs, in words that sustainability and efficiency are now two sides of the same coin.

However, there are several barriers to eco-transportation throughout the entire world: high initial outlays, the lack of required infrastructure, and changes in legislation. These barriers highlight more

the significance of having focused approaches to satisfy all needs of industries and the versatility of the solutions to consider differences in geographic areas. For example, retail and e-commerce industries, which are likely to adopt urban logistics solutions, could benefit from EVs and route optimizing aids, while industries need cutting-edge innovations like green hydrogen vehicles to address the existing payload and range challenges, for example.

Legal restraints and policy support continue to play a central role in driving the take-off of eco-transportation. Areas that have sound policies like the EU show high usage rates and better performance of operations. On the other hand, emergent economy logistics need more public/private collaboration and easy access to infrastructure and funding to implement eco-transportation into their networks.

Other trends automation, climate-smart transport, and green hydrogen solutions for transport provide bright possibilities to enhance eco-transportation strategies. Artificial intelligence, integrated into existing systems, can enhance route planning as well as the management of fleets, and green hydrogen vehicles can serve as potential medium and long-term solutions for inter-and intracity heavy goods vehicle transport. These changes are accompanied by the inclusion of carbon accounting in organization sustainable development reports, pay a testament to the transforming nature of GSCM and its rising role in dealing with environmental issues. From a theoretical point of view, this study strengthens evidence on how sustainability initiatives within the supply chain that affect operations, and the environment will produce a favorable return. The results add value to the existing literature of GSCM by discussing the changes brought on by eco-transportation technologies. Tautologically, each insight offers practical recommendations to firms and policymakers to ramp up adoption, overcome infrastructural deficits, and harness regulation to advance sustainability.

In conclusion, eco-transportation is an enabler of the green efficient, and sustainable supply chain that provides businesses with a way to make more money while contributing to environmental causes. These challenges cut across the entire value chain and need to be addressed to unlock new opportunities for greater industry development and effectiveness across industries and sectors. Through the promotion of innovation, the creation of infrastructures, and working towards alignment of regulations, eco-transportation becomes the cornerstone of the next-generation supply chain system.

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