INTEGRATING CLIMATE RESILIENCE AND CIRCULAR ECONOMY PRINCIPLES IN DEVELOPING GREEN-BLUE LOGISTIC CORRIDORS FOR A ZERO-EMISSION FUTURE

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1. **ABSTRACT:** This invited paper is a discussion on the intersection of climate resilience, the principle of a circular economy, and sustainable logistics within the context of emerging Green-Blue Logistic Corridors. It will analyse how there is an increasing need to decarbonize marine and land logistics networks and sustain economic and environmental equilibrium. It suggests a system of creating zero-emission corridors by combining artificial intelligence (AI), smart materials, and renewable energy systems in accordance with the goals of the UN Sustainable Development Goals (SDGs) and the Paris Agreement. The paper identifies opportunities in which AI-based decision platforms, intelligent materials, and circular logistics systems can jointly turn the maritime and inland transport system into an all-climate-ready and carbon-neutral system.

2. INTRODUCTION

Climate change has caused unprecedented pressures on the economies of the world, ecosystems, and human health due to the acceleration. The increase in global temperature, extreme weather patterns and biodiversity depletion have interfered with supply chains and marine transport networks across the globe. The transport sector, which is the support centre of the global trade, is the source of almost 11 percent of the total emission of greenhouse gases, and hence there is a pressing demand to find mitigation efforts that incorporate technology, innovations and policies (Jain et al., 2024).

Green-Blue Logistic Corridors (GBLCs) is a new concept of updating maritime and terrestrial logistics with sustainable practices. Green corridors focus on the decrease of inland transportation emissions, whereas Blue corridors focus on the low-carbon operations along the maritime routes and ports. Their combination constitutes an interdependent ecosystem that is aimed at realising zero-emission transportation, optimisation of resource flows, and resilience to climate-related disruptions.

The paper will discuss the potential of AI-based technologies, eco-friendly materials, and a circular economy model to decarbonize faster together. It combines both scientific thinking and practical logistics models in order to find out the opportunities, challenges, and policy facilitators to achieve the green-blue logistics systems that are economically viable and regenerative of the environment (Asariotis et al., 2024a).

The last decades experienced a radical change in how countries are considering economic growth, environmental management, and the sustainability of infrastructure systems. The issue of climate change was treated as a remote environmental problem, but nowadays, it is a feature of the policy discussions and industrial planning on the global level. The increase in the average temperatures worldwide, the growing frequency of extreme weather events, and the gradual disappearance of ecological resources have placed sustainability issues on the top of the national agendas. These patterns are especially important to the logistics and maritime sectors, which constitute the foundation of international trade and are pre-disposed to the vulnerabilities of climate. As almost 80-90 percent of the world trade volume is transported by sea, the sustainability and stability of maritime channels and coastal logistics centers are directly associated with the security of economic activities in the world (Alamoush et al., n.d.).

Meanwhile, logistics systems continue to be a significant source of environmental degeneration. About a quarter of the global greenhouse gas emissions are attributed to the transport sector, a substantial portion of which is contributed by freight movement, both inland and by sea. Maritime transport, which is relatively low carbon per tonne-kilometer, is also dependent on fossil fuels and causes carbon dioxide, sulfur oxide, nitrogen oxide and particulate matter emissions. The inland transport systems, which are majorly run by the use of diesel trucks and warehousing systems that consume a lot of energy, also add to the environmental load (Ratna Prabawardani et al., 2024). With the continued growth of international trade, the carbon intensity of logistics has become not only preferable but also necessary to accomplish global climate-related obligations including the Paris Agreement and the United Nations Sustainable Development Goals (SDGs).

To address this increasing urgency, the idea of Green-Blue Logistic Corridors (GBLCs) has become a viable and combined concept of how to steer sustainability changes in both land and maritime transport systems. The focus of green corridors is the use of low-carbon and environmentally efficient inland logistics, which is usually via electrified transportation, integration of renewable energy, and the development of environmentally friendly infrastructure. Blue corridors, in turn, deal with sustainability in sea routes through the promotion of cleaner sea fuels, digital navigation, nature-based coastal protection, and waste and emission minimizing port operations. These green and blue components when connected would form a continuous, end to end sustainable channel where goods can flow at minimum environmental degradation between source and destination (Tsoulfas & Tsoulfas, 2025).

Green-Blue Logistic Corridors have much more than just emissions reduction as its scope of application. Systemically, GBLCs allow reconsidering the concept of infrastructure, the utilization of materials, and the flow of energy in logistics networks. As an illustration, most ports are currently considering the use of renewable energy production, including solar canopies, the integration of offshore wind, and tidal energy platforms, to operate. Inland logistics zones, in their turn, are becoming more and more integrated with battery-electric or hydrogen-powered vehicles, intelligent warehousing, and energy-efficient building designs. Such developments correspond to the principles of the circular economy, according to which the minimization of waste, reuse of materials, and recovery of resources are integrated into the logistics value chain (Asariotis et al., 2024b).

The active development of digital technologies and artificial intelligence is another huge change agent altering the logistics landscape. New AI-powered solutions like digital twins, predictive scheduling applications, and real-time environmental monitoring solutions provide never-before-seen opportunities to enhance the efficiency and sustainability of freight movement. Such technologies are able to predict that a vessel requires maintenance, optimize the route of vessels, reduce the time of idle waiting at ports, and give early warnings of disruptions caused by climatic conditions like sea-level rise, storm surge, or floods of the ports. In fact, digital tools have already proven their worth to minimize the amount of energy consumption and emissions in logistics operations by facilitating better decisionmaking in most cases. Under the GBLC model, AI will be used to organize the multi-modal transport flows, environmental conditions, and enhancement of renewable energy resources utilizations.

In addition to technology, it is also becoming evident that climate adaptability needs to be a part and parcel of logistics planning. The rise of the sea level, in particular, is a significant risk to the long-term operational capabilities of the ports and maritime routes located on the coastline. Some of the largest trade centers in the world like Rotterdam, Singapore, Dubai, Los Angeles and Shanghai are located in low areas that are already experiencing erosion of the coastlines, encroachment by salty waters and increased floods. The effects of rising seas may cause serious downtime, economic and supply chain disruptions without proactive adaptation measures that include high port infrastructure, increased quay walls, floating terminals and nature-based coastal buffers. In such a way, sea-level rise is a key issue to consider when developing resilient Green-Blue Corridors.

The change towards zero-emission logistics also needs supporting policy frameworks, collaboration between the government and the business, and significant investment in green technologies. The trend of decarbonization of the logistics system in the initiatives of the International Maritime Organization (IMO), the European Green Deal, and national net-zero is an indicator of the increased awareness that the concept of sustainability in logistics should be applied in a coordinated and systemic way. Policy however cannot bring change with the required speed. Universities, research centers, port operators, technology companies, and logistics providers need to collaborate to create capacity, share experiences and expand innovations in various locations.

Combined, these trends demonstrate that the international logistics industry is going through a transitional stage that has never been experienced in the history of the sector. The pace of climate change has rendered the old models of transport less viable, and new technologies and sustainability models have paved the way to more sustainable and resilient options. With the help of Green-Blue Logistic Corridors, the logistics industry will be able to make a considerable contribution to the world decarbonization and environmental rejuvenation, offering a holistic route to unite these opportunities. The following sections investigate this transition in more detail, including the context of the environment, the technological facilitators, the links to the circular economy, the aspects that are supported by policy, and the long-term sustainability of the logistics.

3. GLOBAL SUSTAINABILITY ENVIRONMENT

The need to transform the system on a systemic level is supported by scientific evidence. NASA and the IPCC have reported that the last ten years have been the hottest in history with 2024 to come in a new record global temperature. The increasing sea levels, glaciers, and common flooding are still posing risks to the operations of ports and the coastal infrastructure that is an important element in the world logistics chains (Jain et al., 2024).

Stress on the environment extends way beyond changes in temperature. The degradation of soil, lack of water, air pollution, and the disappearance of biodiversity are all threat factors to the stability of the supply system and agricultural networks that sustain the logistics demand. According to the World Atlas of Desertification, more than 75 percent of the soil is already degraded, and the percentage can increase to 90 percent by 2050. Equally, the worldwide water demand is estimated to surpass the sustainable supply by a factor of 40 in 2030.

The I = PAT model (Impact = Population x Affluence x Technology) is a theoretical framework that can be used to measure the overall impact of the demographic, economic, and technological conditions on the environment. The level of technology will have to increase seven times over by 2050 in order to reduce by half the carbon emissions by 2050. This calls on innovation and behavioural and systemic change in the logistics industry (Kulagin et al., 2025).

Therefore, the way to zero-emission logistics is a comprehensive combination of AI, new materials, renewable energy, and circular systems that will be able to regenerate natural capital and ensure the efficiency of trade.

4. GREEN-BLUE LOGISTIC CORRIDORS CONCEPT

A network of links between ports, terminals, and inland logistics hubs based on the use of sustainable energy, smart technologies, and regenerative material flows is defined as Green-Blue Logistic Corridors. They are made in such a way that they minimize the emissions, maximize the energy efficiency, and recover ecosystems and be economically resilient.

These corridors are the vision of zero-emission transport ecosystem, which connects ships and vehicles that are powered by renewable sources, electrification of port processes, and AI-based surveillance platforms. An example of this transition is the European Green Corridors Network, the Clean Energy Shipping Program of the IMO, and the UAE Net Zero 2050 Strategy (Song & Song, 2024). GBLCs are run on the following three principles:

- To reducing carbon footprints and conserving coastal and marine biodiversity, environmental integration.
- To the minimization of waste, re-use of materials, and the encouragement of sustainable packaging and recycling.
- To the predictive logistics and environmental monitoring using AI and IoT, technological intelligence.

The multi-layered model also makes sure that sustainability is integrated into the whole life cycle of logistics, such as sourcing of materials to the final recovery of end-of-life (Liu et al., 2025).

5. SIGNIFICANCE OF SEA-LEVEL HIKES

Rise in sea level is becoming one of the greatest climatic related challenges to the logistics infrastructure in the world particularly in ports, coastal terminals and sea routes. With the swelling of oceans because of the rise in temperature and heightened ice melt, a significant number of the busiest ports in the world in the low-lying coastal areas have been exposed to greater dangers of inundation, storm surge damage, and disruption of long-term operations (Duijndam et al., 2025). The concept of sea-level rise is not only relevant to the environmental issue; it also has direct impacts on the design, operation and futureproofing of Green-Blue Logistic Corridors (GBLCs) by nations.

The majority of global trade flows via maritime ports and any slight rise of sea levels can disrupt the undercarings of ports, destroy storage areas and cut off shipping routes by depositing sediments and eroding coastlines. These issues have direct impact on the economic competitiveness of the areas whose supply chains are based on the coastal logistics (Nicholls & Cazenave, 2010). Unless adjusted to, the rise in the sea level can be translated into frequent downtimes, high insurance rates, and high maintenance costs. To the developing world, these shocks can increase existing trade accessibility and resilience disparities. Therefore, sea-level rise is no longer an option, and logistics planning should take into consideration new ocean dynamics (Griggs & Reguero, 2021).

Based on the GBLC model, climate-resilient design principles should be welcomed because of the increase of sea level. Climate shock can be absorbed by ports through increasing quays, floating logistics platforms, adaptive breakwaters and nature based solutions such as mangrove buffers. A combination of digital technologies, including AI-based flood forecasting, satellite-based surveillance of the coastline, and real-time structural assessment enables one to issue a timely warning and make a prudent decision. These systems help operators to secure assets, reroute traffic, and manage inconveniences before they are converted to costly failures.

Another reason is the importance of the circular economy and net-zero energy transitions due to the increase in the amount of the sea levels. Solar-covered warehouses, offshore wind turbines, tidal energy, and other sources of renewable energy that are produced and used in ports not only reduce emissions but also diversify the sources of power and, consequently, have higher chances to survive during extreme weather. Equally, the sustainable port construction material, such as corrosion-resistant composite and low-carbon concrete, increases the life of the port asset in the salty environments.

Finally, the increase of the sea-level poses a challenge to policy coordination and global collaboration because its impacts are cross-boundary. To speed up the process of establishing the Green-Blue Corridors which may be utilized even under the conditions of future climatic conditions, regional unions which will share climate information, adaptation strategies, and investment patterns could be created. Thus, the sea-level increase is not only a threat, but a force, which propels the logistics industry to go green, become smarter in planning, and offer long-term sustainability promises.

In conclusion, sea-level rise is a significant factor in the design and the work of Green-Blue Logistic Corridors. Climate resilience, smart technology, sustainable materials, and circle strategy can be integrated into the logistics industry to safeguard critical infrastructure, and efforts should go on to achieve the overall goal of zero-emission, future-proof corridors.

6. THE USE OF AI AND ADVANCED MATERIALS IN EMISSION-FREE LOGISTICS

Artificial Intelligence is a strong facilitator of low-carbon logistics. Port and vessel management is being revolutionized with predictive analytics, machine learning, and simulations of digital twins to optimize routes, schedule maintenance, and reduce time wastage. AI systems will be able to predict the energy demand, evaluate environmental risks, and detect inefficiencies in real-time, and this will enhance sustainability performance overall.

The use of AI in supply chain transparency is also increasing. With the combination of blockchain and IoT data, the logistics operators can track emissions and check the correspondence to the carbon reporting standards. Such information-based systems assist organizations to shift towards reactive monitoring to proactive sustainability management (Frikha et al., 2025a).

These digital systems are supplemented by advanced materials. The carbon intensity of vehicles, ships and containers is reduced by lightweight composites, bio- based polymers and recyclable alloys (Uddin et al., 2025). Structural health monitoring and adaptive control of the environment is possible through smart materials with embedded sensors. The interplay of AI and material innovation is core in order to realize energy-efficient, durable, and intelligent logistics infrastructures.

7. INTEGRATION OF CIRCULAR ECONOMY AND RENEWABLE

The shift to a circular logistics system should replace the linear one to be sustainable. The circular economy focuses on closing the material loop that stretches through the lifecycles of products, designing to be repairable, and developing regenerative industrial ecosystems. This in the logistics means reusing packaging, valorizing waste streams, and recovering energy and materials of operations (Frikha et al., 2025b).

Waste-to-energy systems can be integrated into ports and transport terminals, green concrete should be used in the construction process, and renewable-powered cold chains should be implemented. AI can also be used to increase the level of circularity through data analysis on material flows, demand cycles forecasting, and just-in-time recycling logistics support (Ismail et al., 2024).

It is also essential to integrate renewable energy. Ports and vessels can be provided with clean energy by solar photovoltaic installations, offshore wind farms and tidal power systems. The use of AI enabled energy management platforms can synchronize loads, predict renewable supply and liaise with grid networks to ensure the maximum use of renewables. Collectively, resilient climate-neutral corridors rely on renewables, a circular design, and smart energy systems (Acciaro & Wilmsmeier, 2015).

8. POLICY, EDUCATION AND COLLABORATION

Governance, regulation and human capital are essential in the successful implementation of Green-Blue Corridors. The International Maritime Organization (IMO) is actively using the MARPOL Annex VI laws and the Green Corridors Framework to ensure the world is moving towards a decarbonized maritime sector. These targets are supported by the national and regional policies like the European Green Deal and the Net Zero 2050 Vision by the UAE, which encourages green investment and innovations (Alamoush et al., 2020).

Capacity-building and education are also very important. Incorporation of sustainability in the engineering and logistics programs produces the professionals who will be able to design and operate the infrastructure with zero emission. The cooperation between universities, port authorities, privately owned enterprises, and governments speeds up the process of sharing knowledge and its practical implementation (Berkehan Inal & Dere, 2024).

Lastly, there should be an encouragement of the public-private partnership to make the sustainable logistics solutions scalable and affordable. These partnerships can fill the gap between innovation and implementation, as well as make sustainability not only a policy objective but also a working reality.

9. CONCLUSIONS

The logistics business across the world is at a crossroad. The shift to zero-emission activities is not only the solution to the risks of climate but also a modernization of the economic system. Combining climate resilience, AI-driven intelligence, and principles of a circular economy is a holistic path to attaining sustainability in blue (maritime) and green (land-based) corridors.

With the adoption of renewable energy, green materials, and digital optimization, logistics networks can become a source of low-carbon development. The future of global logistics will be determined by the extent to which innovation will be in line with policy, education and community participation. Through proper alliances and future perspective, the Green - Blue Logistic Corridors would be able to rebrand the manner in which the goods are transported such that growth is no longer achieved at the cost of the world.

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11. DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES:

During the preparation of this work, the author(s) used grammerly in order to check the language correctness. After using this tool/service, the author(s) reviewed and edited the content as necessary and take(s) full responsibility for the content of the publication.

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