European Research Studies Journal
Volume XXVII, Issue 2, 2024

pp. 1014-1021

The Role of Intermodal Transport in the Decarbonization of Seaports

Submitted 10/09/24, 1st revision 25/09/24, 2nd revision 01/10/24, accepted 15/10/24

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Abstract:

Purpose: *The purpose of the article is to analyze the role of intermodal transport as a tool to support the decarbonization process of seaports, with a particular focus on the synergies between rail and inland waterway transport.*
Design/Methodology/Approach: *The article is based on an interdisciplinary approach, combining a literature review and case studies of selected seaports and inland ports, such as the Port of Antwerp-Bruges, the Port of Rotterdam, the Port of Amsterdam and the Port of Duisburg.*
Findings: *the results of the study indicate that intermodal transport significantly reduces greenhouse gas emissions by optimizing logistics flows and reducing reliance on carbon-intensive road transport modes. Investment in the development of intermodal infrastructure, such as rail terminals and digital management platforms that support port decarbonization, is crucial.*
Practical implications: *The study's findings underscore the importance of collaboration between seaports as well as inland ports as a model for integrating intermodal transportation. Examples of such partnerships show that the development of joint projects supports decarbonization and improves the efficiency of supply chains at the international level.*
Originality: *The article fills a research gap by analyzing in detail the impact of intermodal transportation on seaport decarbonization processes.*

Keywords: *Carbon footprint, decarbonization, greenhouse gas emissions, intermodal transport, seaports.*

JEL classification: *L91, O32, Q56.*

Paper type: *Research paper.*

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1. Introduction

According to the European Commission, the transportation sector accounts for an average of 5% of the European Union's GDP, playing a key role in both global supply chains and the operations of European companies (European Commission, 2020). However, it should be borne in mind that transport activities also generate significant external costs, such as workplace accidents, noise, congestion, infrastructure land occupation and greenhouse gas emissions.

The goal of sustainable development within the framework of transport policy is to meet transport needs taking into account the lowest possible cost of environmental degradation now and in the future (Togetair, 2024).

These measures are regulated by EU regulations which stipulate that "by 2030, 30% of freight transport over distances greater than 300 km should be carried by means other than road, and by 2050 this rate should exceed 50%" (European Commission, 2011).

The European Union also plans to reduce greenhouse gas emissions generated by means of transport by 90% by 2050 (European Commission, 2020), which is a key element of socio-economic policy for the sustainable development of the transport sector. Togetair's climate report indicates that "by 2050, global demand for freight transport will increase by 226% and associated carbon emissions will increase by 118%, and international freight transport will account for almost half of all emissions generated by the entire sector" (Togetair, 2024).

In light of these projections, seaborne cargo volumes are also expected to grow. According to UNCTAD, seaborne trade is projected to grow at an average annual rate of 2.4% between 2025 and 2029, while container trade is expected to grow at 2.7% (UNCTAD, 2024). Such dynamic growth in cargo volumes requires ports to work hard to streamline operations while implementing decarbonization measures (Karas, 2024).

The introduction of modern technologies in ports and the development of intermodality are key elements of the transformation towards sustainable development. Intermodal transport is now becoming a tool to reduce these emissions by integrating greener and more economical modes of transportation (Jacyna-Gołda *et al.*, 2024).

The aim of the article is to analyze the role of intermodal transport as a key tool in the process of decarbonization of seaports and to answer the research question:

How can the integration of different modes of transport within intermodal systems support the achievement of seaport decarbonization goals?

2. Literature Review – Intermodal Transport

Intermodal transport is currently an important area of activity in freight transport and has been gaining importance for many years, even though the concept of "intermodal" transport was already introduced into public policy in the late 1970s (OECD, 2001).

The concept of "intermodal transport", used in the common terminology in force in the European Union (EU), the United Nations Economic Commission for Europe (UNECE) and the European Conference of Ministers of Transport (ECMT), is defined as a transport system covering the transport of goods using at least two modes of transport, along the entire transport route from the sender to the recipient without changing the loading unit (European Court of Auditors, 2023; United Nations Economic Commission for Europe, 2001).

The intermodal transport system is not only an integrator, but also requires the involvement of many entities cooperating with each other at various stages of cargo flow, including: from forwarders, carriers, infrastructure managers, intermodal terminals, to cargo recipients (Kramarz and Przybylska, 2021), which implies many challenges.

Moving away from road transport and increasing the use of intermodal transport can play a key role in making freight transport in Europe more environmentally friendly. In the Transport White Paper published in 2011 entitled The 'Roadmap to a Single European Transport Area' set a target for the first time to reduce greenhouse gas emissions from the transport sector, with a reduction of 60% by 2050 compared to 1990 figures. However, unlike other sectors of the economy, emissions CO2 from the transport sector did not decrease, but increased by 33% (European Environment Agency, 2023; European Commission, 2011).

Increasing the share of lower-carbon modes of transportation, such as rail and water transport, is a key element in the implementation of a sustainable transportation policy. The implementation of such changes requires not only the shift of significant cargo volumes from road transport to cleaner modes, but also the dynamic development of intermodal transport systems. Intermodal transport, integrating different modes of transport, allows minimizing CO_2 emissions through the efficient use of rail and inland waterways.

At the national level, member states should implement policies that support modal shift, for example, by subsidizing rail and waterway transport and introducing CO_2 fees for road transport. Only a combination of regulatory measures, financial support and operational changes will achieve sustainability goals in the transport sector (UIC, 2024).

Intermodal transportation allows for a significant reduction in greenhouse gas emissions due to the integration of environmentally friendly modes of transportation. Rail and inland waterways are more energy efficient compared to road transport. According to 2024 statistics data, rail transport in the European Union produced 3.3 million metric tons of carbon dioxide ($MtCO_2$) in 2022, down 8% from 2021.

In contrast, rail CO_2 emissions in the EU have fallen by more than 70% since 1990. Rail transportation is considered one of the least polluting modes of transport and accounts for less than 1 percent of transport GHG emissions in the EU (Statista, 2024).

3. The Importance of Intermodal Transport for the Decarbonization of Seaports

Intermodal transport, which combines various modes of transport - such as rail, inland navigation, road and sea transport - into one logistics system is a key solution for the decarbonization of seaports. Thanks to the synergy between individual modes of transport, intermodality enables, among others: optimizing cargo flows, reducing emissions and improving the operational efficiency of ports.

The implementation of intermodal transport in seaports contributes to global climate goals by reducing the reliance on high-emission modes of transport, such as road transport, in favor of greener alternatives, such as rail and inland navigation. Moreover, intermodal transport supports and requires the use of technological innovations (Pyza, 2019), which further increases its efficiency and decarbonization potential.

One of the key aspects of decarbonizing seaports using intermodal transport is the optimization of transport and reducing CO_2 emissions. Shifting cargo from road to rail as part of intermodal logistics solutions can significantly reduce CO_2 emissions. Rail has lower energy consumption per transport unit compared to road transport, which translates into a smaller carbon footprint. Additionally, the development of intermodal terminals in ports enables efficient transhipment and distribution of goods, minimizing downtime and related emissions (Wronka, 2017).

Intermodal transport also contributes to reducing congestion within ports. The use of intermodal transport reduces truck traffic in ports, which leads to reduced congestion and exhaust emissions. Integration of rail and inland transport with port operations allows for more effective distribution of freight traffic, reducing the burden on road infrastructure and improving air quality in the vicinity of ports (Grzybowski, 2022).

The expansion and modernization of intermodal terminals in ports are crucial for effective decarbonization. Modern terminals equipped with advanced transhipment technologies enable fast and efficient transfer of goods between various modes of transport, minimizing emissions related to port operations (Raben, 2016).

The introduction of automated transshipment systems and the integration of modern digital tools allow for increasing the operational efficiency of ports and reducing their carbon footprint.

4. Case Study – Port of Duisburg

The Port of Duisburg, a key inland port in the world, is playing an important role in Europe's logistical transformation toward more sustainable transportation. With its strategic location at the intersection of major transportation corridors and investments in infrastructure and digital technologies, the port has become a model example of how intermodal transport can support the decarbonization of port operations. Although the Port of Duisburg is an inland port, its approach to intermodal transportation and decarbonization can be an inspiration for seaports (Port of Duisburg, 2023).

With the cooperation of seaports such as the Port of Antwerp-Bruges, Port of Rotterdam, Port of Amsterdam and the inland Port of Duisburg, it is possible to create a sustainable supply chain that will contribute to the reduction of greenhouse gas emissions throughout the transportation system (ITF, 2023).

The port of Duisburg and the port of Amsterdam are effectively connected via inland navigation corridors and land and rail corridors. In addition to the existing barge connections, regular rail transport between Amsterdam and Duisburg was launched in 2019. This transport constitutes an important corridor that directly connects the short sea shipping networks and intermodal transport of both ports.

As part of their cooperation, the Port of Duisburg and the Port of Amsterdam plan to implement further projects related to the expansion of port infrastructure, transport transformation and the promotion of sustainable multimodal connections, including rail transport, inland navigation and short sea connections between ports and other European destinations (Port of Duisburg, 2022).

The Port of Duisburg and the Port of Rotterdam are intensifying their cooperation within the Portbase and RheinPorts platforms, setting the goal of digital integration of sea and inland ports. The project is the development of a digital network enabling effective data flow between the ports of Rotterdam, Duisburg and Swiss inland ports.

Digital integration plays a key role in promoting intermodal transport, and the improved flow of information is expected to allow for more effective planning and implementation of transport, which ultimately leads to shortened waiting times and a reduction in greenhouse gas emissions. The cooperation between Duisburg and Rotterdam shows how digitalization can support the development of sustainable

intermodal transport and contribute to the decarbonization of supply chains in Europe (Intermodalnews, 2024).

The Port of Duisburg and the Port of Antwerp-Bruges have entered into a strategic partnership aimed at jointly implementing projects related to the energy transition and the development of hydrogen infrastructure, through the creation of an international hydrogen supply chain and the development of ports as key hydrogen hubs in Europe.

This initiative aims to support intermodal transport, and through the development of hydrogen infrastructure it will enable the powering of zero-emission vehicles and ships, which will significantly contribute to reducing emissions related to the transport of goods (Maritime Economy, 2022).

The Port of Duisburg achieves significant success thanks to the integration of an intermodal transport system that includes inland navigation, rail and road transport. Modern terminals located in the port enable efficient reloading between various means of transport, which contributes to a significant reduction in greenhouse gas emissions.

Moreover, the developed railway network connecting Duisburg with key port centers in Europe, together with inland navigation based on barges powered by LNG gas and electricity, is the foundation of the ecological transport solutions of this port (Port of Duisburg, 2018).

In addition, the innovative digital platform available within the Dusiburg port and partner ports supports intermodal transport management, enabling planning, booking and monitoring of transport in real time. By optimizing routes and reducing empty trips, the platform contributes to reducing CO_2 emissions and improving operational efficiency (Port of Duisburg, 2024).

5. Conclusions

Analysis of the role of intermodal transport in the decarbonization of seaports highlights its potential in achieving global climate goals. By integrating different modes of transport – such as rail, inland navigation, road and sea transport – intermodal systems offer a sustainable solution for reducing greenhouse gas emissions. Such integration not only optimizes goods flows, but also improves operational efficiency.

Key findings point to a significant shift in freight transport from road to rail and inland navigation, which are much more energy efficient and lower emission. The development of intermodal terminals equipped with modern technologies is proving

effective in minimizing operational emissions and increasing the transparency of supply chains.

Strategic collaborations such as those between the Port of Duisburg and the key European seaports – Rotterdam, Amsterdam and Antwerp-Bruges demonstrate the effectiveness of partnerships in promoting sustainable logistics solutions. These initiatives, focused on digital integration, developing hydrogen infrastructure and creating green supply chains, show that joint actions can significantly strengthen the effects of decarbonization initiatives.

To sum up, intermodal transport appears to be a key element of the sustainable transformation of seaports. However, achieving long-term success will require further investment in infrastructure, technological innovation and political support at national and international levels.

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