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# Intermodal and Multimodal Integration in EU Maritime Logistics: Challenges and Strategic Implications

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**Abstract: Maritime logistics is the backbone of freight transport in the European Union (EU), carrying the majority of trade and serving as the critical link between global supply chains and inland markets. This paper examines how intermodal and multimodal transport concepts interact with water transport in the EU context. It reviews recent trends in maritime transport performance and port activity (including 2021–2025 statistics on cargo throughput, container volumes, and traffic flows), and analyzes the integration of liner shipping networks with inland transport systems (rail, road, and inland waterways). Key legal, commercial, operational, and technological interrelations are discussed – from EU policies like the Combined Transport Directive and digitalization initiatives, to the commercial strategies of shipping lines and ports. Findings highlight that a seamless intermodal infrastructure, underpinned by clear legal frameworks and advanced technologies, is essential for efficient and sustainable maritime logistics in Europe. The conclusion underscores strategic implications, noting that strengthening multimodal connectivity and collaboration among actors is vital for Europe's economic resilience and environmental goals.**

***Keywords:*** *Maritime Logistics; Intermodal Transport; Multimodal Transport; Liner Shipping Networks; Port Logistics; Combined Transport Directive; European Green Deal.*

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## I. INTRODUCTION

The EU relies heavily on maritime logistics as a conduit for international trade and internal market supply. In 2022, maritime shipping accounted for about 67.8% of all freight transport performance in the EU (measured in tonne-kilometers), far outpacing road (24.9%), rail (5.5%), and inland waterways (1.6%)[1]. EU seaports handled approximately 3.4 billion tonnes of cargo in 2023, a volume reflecting Europe's vast seaborne trade; this represented a slight decline of 3.9% from 2022 levels, largely due to the disruption of trade with Russia amid the war in Ukraine [2]. Indeed, geopolitical events like the Ukraine conflict have had tangible impacts on EU maritime logistics – for example, grain export routes were disrupted and shipping capacity reduced, while seafarer labor supply from the region was constrained [3]. These shocks, alongside the COVID-19 pandemic's earlier effects, have tested the resilience of EU ports and supply chains.

At the same time, the strategic importance of integrating maritime transport with efficient inland connections has never been clearer. Europe's major hub ports (such as Rotterdam, Antwerp-Bruges, and Hamburg, which remained the top three EU ports in 2023 [2]) depend on extensive rail, barge, and road networks to distribute incoming cargo to hinterland markets. A large portion of containerized freight landing in North Sea ports, for instance, travels onwards to industrial centers in Germany, France, and beyond via multimodal corridors. However, challenges persist: capacity constraints, modal imbalances, and sustainability concerns (e.g. road congestion and emissions) all drive the need for stronger intermodal solutions. The EU has responded with policies to encourage a modal shift from roads to more energy-efficient modes; under the European Green Deal and transport white papers, goals have been set to substantially increase the share of rail and waterway freight by 2030. In line with this, the Combined Transport Directive (Council Directive 92/106/EEC) and related initiatives provide regulatory and fiscal support to intermodal transport operations [4], [5]. This paper explores the

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interplay of these factors by examining (1) the key actors in maritime logistics, (2) definitions and roles of intermodal vs. multimodal transport, (3) the development of combined unitized (containerized) cargo transport, (4) the interrelations between liner shipping networks and intermodal systems (including inland navigation on the Rhine and Danube and port logistics), and finally (5) a conclusion on strategic implications for the EU. The analysis draws on recent data, EU-specific case examples, and scholarly insights (e.g., Tikaradze and Kostadinov [6], Tejwani [7]) to provide a comprehensive, up-to-date perspective.

Maritime transport dominates freight movement in the EU by tonnage. Figure 1 shows the modal split of freight transport (in % of tonne-kilometers) for 2012, 2021, and 2022, illustrating that maritime shipping has consistently carried roughly two-thirds of EU freight. In 2022, about 67.8% of EU freight transport was seaborne, compared to 24.9% by road and much smaller fractions by rail, inland waterways, and air [1]. While maritime remains the principal mode, its share has slipped slightly over the past decade as road transport's share rose, highlighting the ongoing challenge of shifting more cargo to greener modes[1].

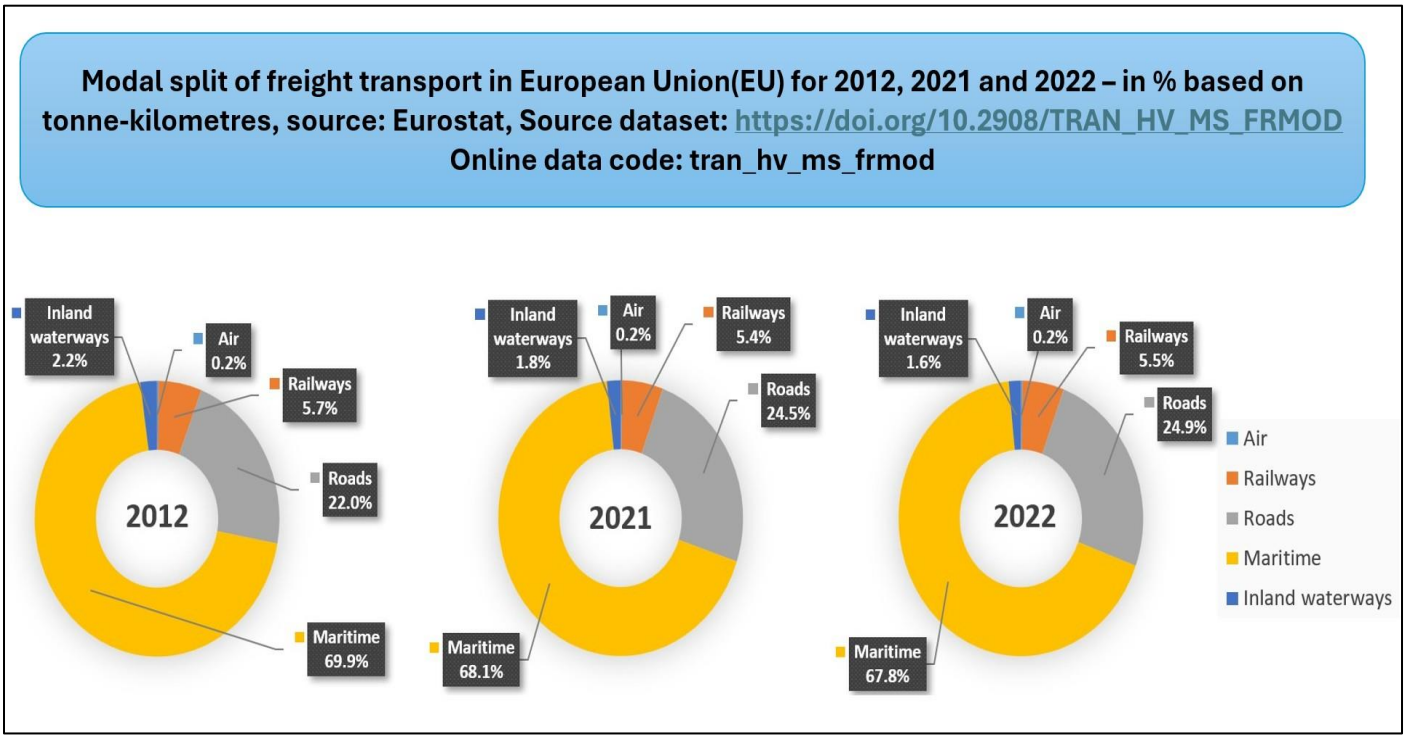


Fig 1 Modal split of freight transport in European Union(EU) for 2012, 2021 and 2022 – in % based on tonne-kilometres[8]. Authors' visualisation based on Eurostat dataset "*Modal split of air, sea and inland freight transport.*" Source: © European Union, 2025 - Eurostat (online data code: tran_hv_ms_frmod). Adapted under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence. Available at: https://ec.europa.eu/eurostat/databrowser/view/TRAN_HV_MS_FRMOD__custom_5228127/bookmark/table?lang=en&bookmarkId=6d6e1a19-1a71-461f-989d-2215bddee762 , DOI URL: https://doi.org/10.2908/TRAN_HV_MS_FRMOD, License: https://creativecommons.org/licenses/by/4.0/

## II. KEY ACTORS IN MARITIME LOGISTICS

Effective maritime logistics involves a network of diverse stakeholders, each with distinct roles but interdependent functions.

➢ *Shippers (Cargo Owners)*

These are the manufacturers, producers, or traders who need to move goods. They initiate demand for transport and often decide routing based on cost, time, and reliability considerations. Shippers benefit from seamless intermodal connections that can deliver door-to-door service and may engage freight forwarders or carriers to orchestrate complex logistics.

➢ *Shipping Lines (Maritime Carriers)*

Shipping Lines (Maritime Carriers): Shipping companies (liner operators for containers, bulk shipping companies, ro-ro ferry operators, etc.) operate the vessels that carry goods by sea. In EU liner shipping, a few major global alliances dominate capacity on main trade lanes, coordinating schedules and port calls. These carriers sometimes act as multimodal transport operators, offering through bills of lading that cover inland legs in addition to the sea voyage. Notably, a "*carrier*" in maritime logistics is not always the ship owner – it can be an operator or logistics provider that charters space and issues a bill of lading. This can complicate legal responsibilities and distinguishing the actual carrier in contractual terms can be challenging, especially when obligations are divided among ship owners, charterers, and freight forwarder [9]. Such complexity matters when determining liability for cargo loss or damage in a multimodal scenario.

➢ *Port Authorities and Terminal Operators*

Ports are pivotal nodes linking sea and land. Port authorities manage infrastructure and regulate port operations, while terminal operating companies handle the loading, unloading, and storage of cargo (containers, bulk goods,

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etc.)[10]. European ports also serve as landlords and facilitators for intermodal connectivity – ensuring there are sufficient rail tracks, barge quays, and road facilities to handle inland distribution. Major port operators (e.g. PSA, APM Terminals, DP World) often invest in streamlining transfer operations from ship to rail or barge[11], [12], [13]. Port community systems (digital platforms) operated by ports help coordinate between shipping lines, customs, and hinterland carriers to smooth cargo flows[14], [15].

- *Hinterland Transport Operators*

These include rail freight operators, inland waterway barge operators, and trucking companies that carry goods to/from ports[16], [17]. In an intermodal chain, they are responsible for the land segments[16]. For example, dedicated freight trains or barge shuttles move containers from seaports to inland depots (dry ports) or logistics hubs. Trucking, while offering flexibility, is often used for initial or final legs due to its door-to-door reach. Many European corridors feature specialized intermodal operators that arrange transshipment and onward carriage (e.g., companies running scheduled rail shuttle services for containers). Collaboration among these operators is crucial – a delay in a train's arrival can hold up a ship's schedule, and vice versa, illustrating the tightly knit operational relation between modes.

- *Freight Forwarders and Logistics Service Providers*

Freight forwarders act as intermediaries that plan and manage shipments on behalf of shippers, often across multiple carriers and modes. They may consolidate cargo, book space on ships/trains, handle documentation, and provide value-added services. In multimodal transport, forwarders can assume the role of a Multimodal Transport Operator (MTO), taking end-to-end responsibility under a single contract (issuing a FIATA multimodal bill of lading, for instance). Large 3PL/4PL logistics providers in the EU (e.g., DHL, DB Schenker, Kuehne+Nagel) offer integrated solutions that combine ocean transport with trucking, rail, and warehousing[18], [19], [20]. Their involvement is key to coordinating the complex logistics chain and ensuring that maritime and inland legs are synchronized commercially and operationally.

- *Regulators and Policy Makers*

The EU institutions (European Commission, etc.), national governments, and international organizations (e.g., International Maritime Organization for safety/environment, but also river commissions for inland waterways) form the regulatory framework within which maritime logistics operates. They set policies on issues like competition (e.g., the EU Consortia Block Exemption allowing shipping alliances), safety and security regulations, customs procedures at ports, and environmental standards (such as sulfur emission limits or decarbonization targets). In the intermodal domain, EU policymakers have been active in promoting combined transport – for instance, Combined Transport Directive (Council Directive 92/106/EEC) was specifically aimed at boosting intermodal (road-rail-water) freight by removing certain road haulage restrictions and providing tax incentives [4]. Regulators also work on harmonizing technical standards across modes (rail gauge, road vehicle weights, etc.) and funding infrastructure through programs like the Connecting Europe Facility[21]. Another important aspect is legal frameworks governing carriage contracts and liability across modes – currently a patchwork of conventions applies (maritime, road, rail each covered by different rules), which the EU and international bodies have tried to reconcile for smoother multimodal operations.

By interacting closely, these actors form an ecosystem that keeps freight moving from origin to destination. Collaboration is essential: ports act as facilitators between shipping lines and hinterland carriers; shipping lines coordinate with forwarders and inland operators to offer integrated services; and regulators set the stage to enable (or sometimes constrain) these collaborations through policy. The following sections delve deeper into how intermodal and multimodal concepts are defined in this context and how these stakeholders and frameworks come together in practice.

## III. INTERMODAL AND MULTIMODAL TRANSPORT: DEFINITIONS AND ROLES

The terms intermodal and multimodal transport are often used interchangeably, but they have distinct meanings in logistics. Both involve moving goods by a sequence of at least two different transport modes (e.g., a combination of ship, rail, truck, or barge)[22]. The key difference lies in the shipping arrangement and handling of the cargo:

- Multimodal transport typically refers to a single transport contract (and one responsible carrier or MTO) covering the entire journey from origin to destination, even though multiple modes and carriers may be involved. In a multimodal shipment, the shipper deals with one lead carrier who takes full responsibility for door-to-door delivery (often issuing a Through Bill of Lading or Multimodal Bill of Lading). For example, a logistics provider might contract to move goods from a factory in Hungary to a customer in Spain via truck, then ship, then rail, all under one contract. The advantage is simplicity for the shipper – one contact point and unified documentation. The multimodal carrier internally arranges the different legs. In contractual terms, one carrier assumes responsibility for the entire journey, even if subcontractors perform parts of it [22].

- Intermodal transport, on the other hand, emphasizes the seamless movement of goods in the same unit or vehicle across multiple modes, but often under separate contracts for each leg. A classic example is container transport: a container can be hauled by a truck to a rail terminal, carried by train to a seaport, loaded on a ship, then transferred to a barge or another truck, all without unpacking the contents. The key feature is that the cargo stays in the same loading unit (container, swap-body, trailer, etc.) throughout the journey, and handling is only of the unit, not the goods themselves. This minimizes cargo handling, reduces damage and delays, and improves efficiency. In intermodal logistics, different carriers might handle each segment (with their own contracts – e.g., a trucking contract, a sea freight contract, etc.), so responsibility is segmented by leg

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[22]. Coordination between parties is therefore crucial to ensure smooth transfers.

In practice, these concepts overlap. One can have an intermodal operation (multiple modes, containerized cargo) that is also multimodal in contract (one through contract for the shipper). For instance, many liner shipping companies offer door-to-door rates where they act as a multimodal carrier: the container is carried intermodally (truck + ship + rail), but the shipper only contracts with the shipping line for the entire journey. Conversely, a purely intermodal arrangement might see a shipper separately organize each leg (merchant haulage in container shipping, where the shipper arranges the truck leg independently from the sea carrier).

The role of intermodal transport in EU logistics is pivotal because it leverages the strengths of each mode: long-distance economies of rail or barge or short-sea shipping, combined with the flexibility of road for first/last mile. By using standardized units like ISO containers or swap-bodies, intermodal transport enables efficient transfers at terminals and ports without repacking cargo. This reduces handling costs and transit times. It also has environmental benefits – shifting freight off highways onto rail or barge can significantly cut $CO_2$ emissions and congestion. As a result, EU policy has strongly promoted intermodal solutions as a path to sustainability. According to EU forecasts, freight transport demand is growing rapidly (with road freight projected to increase ~40% by 2030 and ~80% by 2050), so shifting a greater share to rail and water is essential to meet climate targets [4]. The Combined Transport Directive (92/106/EEC) explicitly aims to facilitate this shift by defining combined transport as a form of intermodal transport where the longest leg is by rail, inland waterway or sea, and any road leg is as short as possible (e.g., only a local pickup/delivery within 150 km of a port or terminal) [4]. Under this directive, intermodal journeys meeting those criteria enjoy certain exemptions (like being exempt from some road cabotage limits and eligible for fiscal incentives) to encourage their use [4].

From an operational perspective, successful intermodal transport requires an integrated network of transshipment hubs (e.g. rail terminals, inland ports, logistics platforms) where containers or trailers can be quickly transferred between modes. It also depends on standardization – not just of units (containers, pallet dimensions, etc.) but also of information flow (through electronic data interchange, tracking systems) so that each handover is smooth. Modern logistics increasingly leverages digital platforms to coordinate these intermodal handovers in real time. In the EU, initiatives like the Electronic Freight Transport Information (eFTI) regulation are establishing frameworks for digital exchange of shipment data across all modes, ensuring that a piece of regulatory or logistic information entered at one point (say, an electronic consignment note eCMR for a truck) can be re-used by others (like port or rail authorities) without paper documents [6], [23], [24]. This kind of digital integration underpins intermodal efficiency, as discussed further below.

In summary, multimodal transport highlights unified management and liability under one contract, whereas intermodal transport highlights the method of conveyance (standard units across modes with minimal cargo handling). Both concepts aim to improve the efficiency and reach of maritime logistics by tying in land transport. In the EU context, they are crucial for connecting coastal gateways with inland economic centers, and both benefit from supportive policies and technological innovations designed to break down barriers between transport modes.

## IV. COMBINED UNITIZED CARGO TRANSPORT

One of the most significant developments in maritime logistics over the past few decades is the rise of unitized cargo systems, especially containerization. Unitization refers to packing cargo into standardized units (containers, swap bodies, pallets, roll-on/roll-off trailers, etc.) that can be handled as a single entity across different modes. This concept is at the heart of intermodal transport, as it enables goods to be transferred between ship, rail, and road without being unpacked. In Europe, combined transport of unitized loads has been strongly encouraged as a way to boost efficiency and sustainability in freight.

Container shipping, in particular, has grown dramatically and now dominates general cargo trade. The EU's ports have seen a steady increase in container throughput up until recent years. Containerized goods range from manufactured products and electronics to foodstuffs – virtually any item can travel in a box. The scale of container operations in the EU is immense: in 2023, about 92.4 million TEUs (twenty-foot equivalent units) were handled in the main EU ports, a slight drop (-4.4%) from the previous year [2]. This minor decline reflects short-term factors like economic conditions and war-related disruptions; however, the long-term trajectory has been upward. Major European ports have expanded their container terminals to accommodate ever-larger ships (with capacities of 20,000+ TEU) and to facilitate rapid intermodal transfers to inland transport. For example, Spain handled the largest share of containers in Europe in 2023 (16.4 million TEU, ~17.7% of the EU total), followed by the Netherlands, Germany, Belgium, and Italy – collectively, five countries accounted for over 70% of EU container port volume [2].

Roll-on/Roll-off (Ro-Ro) transport is another key form of unitized cargo in Europe. On many short-sea routes (such as across the North Sea, Baltic, and Mediterranean), trucks or trailers are driven onto ferries or ro-ro ships and carried to the next port, then driven off – effectively treating the ship as a moving highway. This is common for trade between the UK and continental Europe, in the Baltic Sea (Finland-Sweden-Germany routes, etc.), and in the Mediterranean (Italy-Greece, for example). Ro-Ro allows accompanied transport (the truck driver travels with the vehicle) or unaccompanied (only the trailer is shipped, the tractor unit and driver do not make the sea crossing). Unaccompanied ro-ro has become popular as it uses trailers or containers as units, avoiding the need for the driver to be idle during sea transit. It's an important component of EU multimodal logistics, complementary to containers. Many EU ports (like Antwerp-Bruges) specialize in ro-ro, handling millions of vehicles and trailers annually[25], [26].

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The benefits of these unitized transport systems are evident in operational efficiency and speed. Cargo in containers or trailers can be transshipped rapidly: cranes or ramps handle standardized units at ports and terminals, achieving high throughput rates. This has reduced dwell times in ports and border crossings, as well as labor costs. Moreover, unitization greatly improves cargo security and reduces damage, since goods are not individually handled at transfers. For shippers, it means lower insurance and less spoilage. The dominance of containerization in maritime logistics also enables global interconnectivity – a container from Asia can seamlessly travel deep into Europe by train or barge after arriving by sea, since railcars and barges are designed to carry the same ISO containers.

It's worth noting the composition of cargo in EU ports: in 2023, around 38% of the goods handled in main EU ports were liquid bulk (petroleum, LNG, etc.), and dry bulk (like coal, ores, grains) also constituted a large share [2]. However, the unitized cargo segment (containers and ro-ro), while measured by weight is smaller than bulk, is critical in terms of value and supply chain impact. Most high-value manufactured goods and just-in-time supply chains rely on containers. EU port activity data show that container volumes, measured in TEUs, grew robustly from the 2010s until 2019, hit a dip in 2020 due to COVID-19, then rebounded in 2021 to reach new highs. The slight easing in 2022–2023 still leaves volumes significantly above pre-2010 [2]. This growth has gone hand-in-hand with investments in combined transport infrastructure – e.g., new rail freight corridors from ports, automated container handling systems, and expansion of inland depots to store and reposition empty containers.

The figure 2 below shows the volume of containers handled in main EU ports from 2008 to 2023 (in millions of TEUs), distinguishing total volume (blue line) and the subset of loaded (red) vs. empty (yellow) containers[2], [27]. Overall, EU container traffic experienced steady growth over the past decade, reflecting increasing trade and the shift toward containerization. From around 60 million TEUs in 2009, volumes climbed to a peak of 99.8 million TEUs by 2021. There was a slight downturn in 2022 and 2023 – with 92.4 million TEUs in 2023, down 4.4% compared to 2022 [2], [27] - partly due to economic cooling and disruptions in global trade. Notably, the gap between the loaded (red) and total (blue) lines indicates the proportion of empty containers moved; in 2023, empty containers accounted for a noticeable share (the decline in loaded boxes was -4.7% vs. -2.8% for empties)[2], [27], signaling logistical repositioning needs. Despite short-term fluctuations, the long-term trend underscores the growing importance of containerized, unitized cargo transport in Europe's multimodal logistics [2], [27].

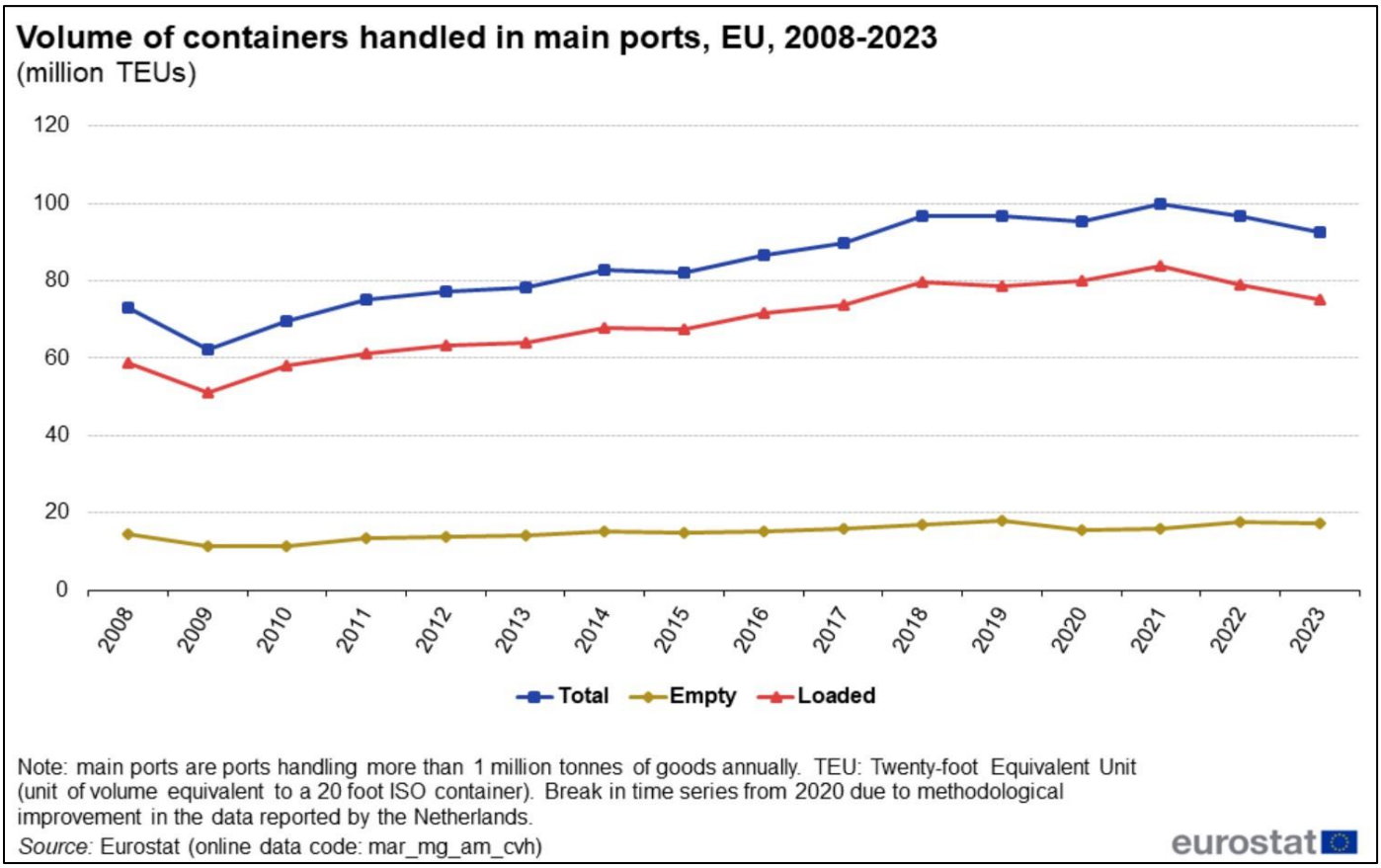


Fig 2 Volume of containers handled in main ports, EU, 2008-2023 (million TEUs) [2], [27], Source: © European Union, 2024 - Eurostat (online data code: mar_mg_am_cvh). Reproduced under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Volume_of_containers_handled_in_main_ports,_EU,_2008-2023_(million_TEUs).png , License: https://creativecommons.org/licenses/by/4.0/

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Beyond containers, swap bodies and pallets also facilitate unitized intermodal transport within Europe. Swap bodies are demountable cargo boxes (often for trucks) that can be transferred to trains. Palletization of goods (common in warehousing and trucking) complements containerization by unitizing smaller goods for handling by forklifts, though pallets are typically consolidated into larger units (trailers or containers) for long-distance moves.

The EU's commitment to combined unitized transport is also evident in its support for urban consolidation centers and dry ports. Dry ports are inland terminals directly connected to seaports by rail or barge, where international containers can be customs-cleared and transferred to trucks for local delivery. Examples include places like Duisburg in Germany or Zaragoza in Spain – these serve as inland extensions of seaports. Duisburg, often cited as the world's largest inland port, handled on the order of 3.6 million TEUs in 2023 (down from 4.0 million in 2022) through its waterways and rail connections, illustrating the massive scale of hinterland intermodal operations [28]. Such hubs effectively allow unitized cargo to move deep into Europe's interior with minimal friction, alleviating coastal port congestion and bringing logistics services closer to end markets.

In summary, combined unitized transport (especially containerization) has revolutionized maritime logistics by enabling true multimodal integration. Its continued growth in the EU has been a cornerstone of increasing efficiency and reducing the cost per unit of freight. The slight recent declines in volume are viewed as cyclical; structurally, the reliance on containers and trailers is expected only to increase as supply chains become more integrated. The next section will examine how these unitized flows interact with liner shipping networks and what interrelations exist between the maritime leg and the inland legs of the logistics chain.

## V. INTERRELATIONS BETWEEN LINER SHIPPING AND INTERMODAL SYSTEMS

The interface between liner shipping (regular maritime services, particularly container lines) and intermodal transport systems is where maritime logistics truly meets the inland world. In Europe, these interrelations are evident in operational, commercial, legal, and technological dimensions.

- *Operational Interrelations*

Liner shipping schedules and port calls must be coordinated with inland transport schedules to ensure timely onward movement of cargo. When a large container ship (e.g., 18,000+ TEU) arrives at a port like Rotterdam or Antwerp, thousands of containers may need to be moved out by rail, barge, or truck in the subsequent days. Ports and hinterland operators coordinate closely via scheduling systems – for instance, barge and train slots are arranged based on expected ship discharge. If a vessel is delayed at sea, inland carriers and terminals must adjust their plans (and vice versa, if a train is delayed, the port may face storage pile-ups). This requires a high level of logistics synchronization. Some European ports have implemented appointment systems for trucks and digital platforms for barge scheduling to align with ship operations, reducing wait times.

The inland waterways offer a critical buffer and capacity for these surges. On the Rhine River, daily barge services carry containers from North Sea ports to hinterland depots in Germany, France, Switzerland, functioning like floating conveyor belts. A single barge can carry hundreds of TEUs, taking the equivalent of hundreds of trucks off the road. For example, Rotterdam has historically moved a substantial portion of its containers by barge (around 30–35% of hinterland traffic) and by rail (10–15%), with the remainder by road [29], [30]. However, recent trends have shown some shifts – a German report noted that from 2018 onwards, Rotterdam and Antwerp saw an increasing share of containers being moved by truck, with barge usage somewhat declining [29]. By 2022, Rotterdam's inland modal split was roughly 59% road, 30% inland shipping, and 11% rail [29]. This indicates that despite efforts to boost rail and barge, road haulage has grown, possibly due to capacity constraints or reliability issues in rail/barge networks. The port of Hamburg, on the other hand, has managed to increase the rail share of its hinterland traffic significantly, shifting volumes from road to rail without losing barge volumes [29]. These differences underscore how operational interrelations are also impacted by infrastructure and geography – Hamburg is closer to its hinterland markets (many in southern Germany) and has excellent rail links, whereas Rotterdam/Antwerp serve very large hinterlands extending further south and east, where long barge trips or multiple rail transfers might be needed.

Inland navigation along the Danube is another intermodal interaction with maritime logistics, though it has untapped potential. The Danube connects the Black Sea (via Danube–Black Sea Canal to Constanța and Năvodari Ports ) to Central Europe (Germany via the Main-Danube Canal, and many Balkan and Eastern European countries along its route). Liner services (in this case, often river-sea or short-sea operators) can carry goods up the Danube, complementing the ocean liners that call at Constanța. However, issues like variable water levels, lock constraints, and less developed terminal infrastructure have limited the Danube's use. The EU's Rhine–Danube Transport Corridor initiative aims to improve this, recognizing that better integration of the Danube inland shipping with maritime networks could enhance connectivity for landlocked parts of Europe. For instance, container barge services on the Danube exist but are relatively infrequent; improving their reliability could divert more containers from road/rail to the waterway for countries like Austria, Hungary, Serbia or Bulgaria.

- *Commercial and Strategic Interrelations*

In recent years, major ocean carriers have pursued vertical integration strategies, effectively blurring the line between maritime and inland transport services[31], [32]. Carriers like Maersk, MSC, CMA CGM, and others now offer end-to-end logistics solutions – a concept often phrased as "*from factory to store door*." This means that a shipping line might arrange rail or truck transport for a customer's cargo in addition to the sea leg, streamlining documentation flows [31]. Such offerings transform the carrier into a multimodal

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transport operator, aligning with the multimodal definition of one responsible party. For example, Maersk acquired logistics companies and developed its inland depot network in Europe, aiming to handle landside logistics for clients[33], [34], [35]. Similarly, CMA CGM acquired a stake in rail operators and built out its CEVA Logistics arm[36]. The commercial rationale is to capture more value and ensure better control over the supply chain timing – if a carrier can manage the entire route, they can optimize handovers and minimize delays.

Alliances among carriers also have intermodal implications. When carriers in an alliance concentrate their port calls at certain hubs (say, Ocean Alliance focusing on Piraeus or The Alliance on Hamburg, etc.), those ports see surges that require robust inland distribution[37], [38]. An allied network might choose a port partly based on hinterland connectivity offerings. Thus, port competition in Europe often hinges on how well a port authority and its national infrastructure can handle intermodal tasks. For instance, Mediterranean ports like Valencia or Piraeus have improved rail links to attract more Asia–Europe services as alternatives to Northern Range ports, aiming to serve central European markets[39]. Legal frameworks like the EU's Trans-European Transport Network (TEN-T) designate core corridors that integrate ports with rail and road links, guiding investments so that commercial routing choices can expand beyond traditional patterns[40].

- *Legal Perspective*

From a legal perspective, there are important interrelations in multimodal transport contracts. When a shipping line or forwarder issues a through bill of lading covering, say, an ocean leg and a trucking leg, the question arises: what law governs liability if cargo is damaged? Maritime transport is governed by regimes like the Hague-Visby Rules or Hamburg Rules[41], [42], while road transport in Europe is under the CMR Convention[43], rail under CIM (within OTIF's COTIF Convention[44]), and inland waterway under yet other rules (like CMNI [45]). There is currently no single unified liability regime enforced across all of these in the EU – the attempt at a solution, the Rotterdam Rules (2009), was an international convention intended to cover multimodal carriage that includes a sea leg, but it has not been widely ratified (most EU countries have not adopted it)[46]. As a result, determining liability in intermodal incidents can be complex. Courts may have to apply a "*network system*" – i.e., figure out in which leg the damage occurred and apply that leg's convention, or if it's not pinpointable, possibly default to the contract terms. The difficulty of carrier identification and liability attribution when responsibilities are divided among multiple parties in different legs must be emphasized [47]. For instance, if cargo in a container is sound when loaded on a ship in Antwerp but is found damaged at a Hungarian rail terminal, is the maritime carrier liable under maritime law, or the rail carrier under rail law? Such questions illustrate the legal interrelations that must be managed through carefully drafted contracts and insurance. The EU has not yet imposed a single rule, but it encourages standard contracts and digital documentation to mitigate disputes.

- *Technological Interrelations*

Technology is increasingly the glue that links maritime and inland logistics. Digital platforms and data exchange allow real-time visibility of shipments across modes[48], [49], [50]. For example, port community systems integrate with rail and trucking appointment systems to ensure that as soon as a container is offloaded from a ship, the relevant parties (customs, trucking companies, rail operators) are alerted and can arrange pickup. Tracking and telemetry (often via Radio-Frequency Identification RFID on containers or GPS on trucks and wagons) enable continuous monitoring of cargo location, which is crucial for managing just-in-time supply chains that span sea and land.

According to Tejwani, the maritime sector is harnessing emerging technologies like Automatic Identification System (AIS) data, big data analytics, and autonomous systems to optimize operations [7]. The use of real-time AIS (which provides live information on ship locations and speeds) coupled with predictive analytics can improve port scheduling and hinterland coordination. For instance, if a ship will arrive early, the system can notify rail terminals to be ready sooner, or if it's late, trucking companies can adjust driver assignments. Big data analysis of patterns can also help optimize routes: one project cited by Tejwani involves using AIS and other sensor data to predict optimal vessel arrival times and thus coordinate with berth and hinterland transport availability [7]. In the near future, autonomous vehicles and vessels could further smooth intermodal transfers – e.g., autonomous yard vehicles moving containers in port, or even autonomous barges shuttling between port and inland terminal. The role of 5G/6G communications and Internet of Things is also to provide the bandwidth for all these actors' systems to connect, from ship bridges to port cranes to truck drivers' apps.

Crucially, digital documentation and standards are being advanced to integrate modes legally and informationally. As noted by Tikaradze and Kostadinov, transitioning from paper-based documents (like the traditional paper Bill of Lading) to electronic formats can greatly enhance efficiency and reduce delays in multimodal chains [6]. An electronic Bill of Lading (eB/L) can be transmitted instantly to a port or to a rail carrier, whereas a paper B/L might have to be couriered or physically present, potentially holding up cargo release. By embracing eB/Ls and platforms like blockchain-based document exchange, carriers and ports can shorten the time ships spend in port and enable containers to be released to onward carriers more quickly [6]. Tikaradze and Kostadinov highlight that fully digitizing transport documents means containers can be reintroduced into circulation faster and ships can depart sooner, as clearance is done in seconds rather than days [6]. The EU's Electronic Freight Transport Information (eFTI) Regulation (EU) 2020/1056 requires authorities to accept digital freight documents and will create a common data framework for all modes[6], [23], [24].

Another area of technological interrelation is safety and security: ports are implementing single windows for customs and security filings that cover cargo through its entire journey. For instance, a single security filing might be accepted for a

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container's sea leg and also meet rail security requirements at the Channel Tunnel, avoiding duplicate filings. The more that data systems of maritime and inland transport talk to each other, the more fluid the logistics chain becomes.

➢ *Inland Ports and Dry Ports as Intermodal Nodes*

Facilities like Duisburg (Germany), Rzepin (Poland), or Metz (France) serve as inland extensions of seaports and epitomize the interrelation of modes [51], [52]. Take Duisburg: it is a hub where barges from Antwerp/Rotterdam unload containers, which are then put on trains or trucks for further transport – or vice versa for exports[51], [53]. The port of Duisburg is even co-located with rail freight terminals and distribution centers, making it a multi-modal logistics campus[51]. This integration means that liner shipping companies often consider such inland hubs in their network design. Some ocean carriers run block trains (dedicated full train loads) from ports to inland hubs under their name, effectively treating the inland leg as part of their service network.

Inland waterway operators too coordinate with sea carriers; a barge operator on the Rhine might time departures from Rotterdam based on when the big Asia-Europe ships arrive, and sea carriers may even use barges to reposition empty containers to where exporters need them inland.

In summary, the interrelations between liner shipping and intermodal transport in the EU are multi-faceted. Operationally, the success of a shipping service is tied to the efficiency of hinterland connections. Commercially, carriers are integrating services and collaborating with ports and inland operators to offer end-to-end solutions. Legally, each mode's framework must be navigated to provide a coherent service to the shipper, and reforms are gradually addressing these gaps. Technologically, digital integration is knitting together the modes in real time, significantly improving visibility and efficiency. The net effect of these interrelations is that maritime logistics can no longer be seen in isolation – it is part of a broader logistics system. A container's journey does not end when the ship berths; the strategic competitiveness of EU supply chains depends on what happens in the next 48 hours as that container travels by rail or barge to its final destination. Conversely, the viability of long inland transport routes (like a rail freight corridor across Europe) often depends on the flows generated by maritime trade. Thus, the synergy between sea and land transport is essential for Europe's trade facilitation. As Tejwani alludes, embracing new technology and data-driven coordination in this synergy is key to coping with rising demand and sustainability pressures [7]. In the final section, the paper summarizes what these interrelations imply for strategy and policy moving forward.

## VI. CONCLUSION AND STRATEGIC IMPLICATIONS

The examination of EU maritime logistics and its intermodal and multimodal linkages reveals a highly interconnected system. Maritime transport carries the lion's share of Europe's freight, but it cannot function effectively without robust inland transport integration. The strategic implications of the interrelations identified are several:

➢ *Enhancing Infrastructure and Capacity:*

To maintain and improve the flow of goods, the EU must continue investing in intermodal infrastructure – high-capacity rail corridors, efficient inland waterways, modern ports, and transshipment terminals. The slight downturn in maritime volumes in 2023 [2] should not mask the long-term growth trend; freight volumes are expected to rise substantially by 2030 [4], and existing road networks alone cannot handle a significant increase without severe congestion and environmental costs. Therefore, projects that increase rail freight capacity (e.g., upgrades to cross-border rail lines, deployment of longer and heavier trains, better signaling systems) and inland waterway reliability (e.g., maintaining navigable water levels, improving lock infrastructure on the Danube) are strategically vital. The EU's TEN-T core network corridors and funding mechanisms should prioritize eliminating bottlenecks where maritime and land modes connect – such as enhancing rail access to major ports, expanding quay and crane capacity for inland barges, and developing more dry ports in the hinterland. These investments yield a network effect: every improvement in an inland corridor extends the effective reach of maritime logistics and vice versa.

➢ *Policy and Regulatory Support for Mode Integration:*

The research highlights that policy frameworks like the Combined Transport Directive have been beneficial, but further support is needed. Streamlining customs and administrative procedures for multimodal journeys will reduce delays – the eFTI regulation is a step in the right direction, mandating digital data acceptance across modes. Likewise, revisiting and updating liability regimes could provide greater legal certainty for multimodal transport operators (for instance, encouraging the adoption of uniform rules or at least clear default rules for door-to-door contracts). The paper underscores the importance of legal clarity in multimodal carrier responsibilities [47], suggesting that shippers and carriers alike would benefit from knowing exactly who is accountable at each stage. The EU might consider promoting a continent-wide standard multimodal contract of carriage or pushing for ratification of conventions that facilitate liability harmonization.

➢ *Environmental and Energy Transition:*

Intermodal transport is not just a logistical necessity but a cornerstone of the EU's sustainability strategy. Shifting freight from road to cleaner modes like ships, barges, and trains will significantly cut transport emissions. The analysis showed maritime and inland waterways are far more energy-efficient per tonne-km than trucking. Thus, interrelations in maritime logistics will also evolve with the decarbonization agenda: we can expect more short-sea shipping (as a lower-emission alternative for intra-Europe freight), integration of electrified rail for long hauls, and possibly the use of alternative fuels in ships and equipment. Strategically, this means EU logistics players must innovate – e.g., ports providing shore power and hydrogen bunkering (to green the sea leg) and electrified cranes and locomotives (to green the

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land leg). The EU's forthcoming FuelEU Maritime [54] and alternative fuels infrastructure regulations will push this forward[55]. The strong intermodal links could help here: for example, a robust rail connection to a port can offset some emissions of an ultra-large vessel by ensuring minimal truck usage. Policymakers should continue to incentivize shippers to choose greener combined transport options, perhaps by internalizing carbon costs (making road transport pay for its emissions impact, thus making intermodal options more financially attractive).

- *Technological Innovation and Digitalization:*

The future of maritime logistics in Europe will be defined by how well technology is harnessed to integrate modes. The findings from Tejwani indicate that advanced analytics, AI, and automation will reshape operations [7]. Strategically, stakeholders should invest in visibility platforms that give end-to-end tracking of shipments across modes, and in automation to streamline transfers (e.g., automated cranes, autonomous yard vehicles, automated freight trains)[56]. Data sharing among actors – underpinned by trust and possibly blockchain for security – can reduce inefficiencies like empty container repositioning (platforms can match empty equipment with nearby export needs, for instance). The EU can facilitate a common digital infrastructure (perhaps expanding projects like the Digital Transport & Logistics Forum[57]) to ensure interoperability of systems between shipping lines, port terminals, railways, and trucking companies. Ultimately, a fully digital multimodal logistics environment could drastically cut administrative overhead and waiting times, effectively increasing capacity without physical expansion.

- *Collaboration and Integrated Planning:*

A clear takeaway is that no actor can optimize the system alone. Shipping lines, port authorities, rail and barge operators, and regulators need to collaborate on planning and problem-solving. One example is coordinating contingency plans: if a major port is disrupted (as seen during occasional strikes or incidents), having pre-arranged alternate gateways and rerouting strategies via other modes can keep supply chains running. The EU's freight corridors should be managed with input from maritime stakeholders, not just land transport agencies, to ensure alignment of capacity – for instance, scheduling maintenance on rail lines with consideration of peak port seasons. Strategic forums that bring together all players (like the European Ports Forum, or initiatives under programs such as Connecting Europe Facility) should be used to identify weak links and future demand hotspots.

In conclusion, the interrelations between maritime logistics and intermodal/multimodal transport in Europe form a complex, dynamic system that is essential to the region's economy. Maintaining fluid connectivity from ship to shore to hinterland is a strategic imperative. The period from 2021–2025, marked by volatility in trade volumes and external shocks, has demonstrated both the strengths and the areas for improvement in this system. Europe's liner shipping sector and its extensive inland transport network are deeply intertwined – success in one domain depends on efficiency in the other. By continuing to integrate legal frameworks, invest in infrastructure, foster technological innovation, and encourage collaboration, the EU can ensure that its maritime logistics and intermodal transport system remains a world-class enabler of trade. This integrated approach will help achieve policy objectives (like modal shift and decarbonization) and bolster the competitiveness of European industries reliant on timely and cost-effective logistics. The future will likely see an even more seamless blend of modes – truly "*synchromodal*" logistics where the best mode is used for each leg in real time – and the EU is poised to be at the forefront of this evolution through the strategic actions it takes today.

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