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THE ROLE OF THE TRANS-EUROPEAN TRANSPORT NETWORK (TEN-T) IN IMPROVING FREIGHT TRANSPORT IN THE EUROPEAN UNION

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Abstract

The Trans-European Transport Network (TEN-T) is a key initiative of the European Union aimed at enhancing the efficiency, connectivity, and reliability of freight transport across Europe. This paper examines its impact on logistics performance, trade flows, and regional integration within the EU. The analysis is based on academic literature and institutional reports, focusing on how transport connectivity influences supply chain efficiency and economic coordination between member states. The findings indicate that stronger integration into TEN-T corridors is associated with higher logistics efficiency, while less connected regions continue to experience structural delays and weaker transport performance. The study also shows that improved connectivity supports the development of multimodal transport systems and enhances the overall reliability of freight movement. However, the effects remain uneven due to infrastructure gaps, differences in investment levels, and coordination challenges between countries. Overall, TEN-T plays a significant role in strengthening European logistics systems, but its full effectiveness depends on achieving a more integrated and continuously connected transport network across all regions

1. Introduction

More than 70% of global trade is transported by sea, yet the complexity behind the movement of everyday goods is often overlooked. What appears as a simple purchase in a store is in fact the result of a highly interconnected logistics system operating across countries, continents, and multiple transport modes.

Within the European Union (EU), this system links producers, businesses, and consumers, enabling the efficient movement of goods both within the region and internationally. However, the effectiveness of this system depends on the strength and reliability of its transport connections. To address this, the EU established the Trans-European Transport Network (TEN-T), an integrated infrastructure framework designed to improve connectivity, reduce bottlenecks, and enhance the efficiency of freight flows across member states. Over time, this initiative has been supported by significant financial investment, reflecting its strategic importance for European integration and economic competitiveness.

Within Europe, freight transport is dominated by land-based logistics, with road transport playing a central role due to its flexibility and accessibility for short and medium distances. It is widely used for both domestic and cross-border trade, where efficiency and timing are critical for supply chain performance.

However, European logistics cannot be understood in isolation from global trade. Long-distance freight between major economic regions is primarily conducted by maritime transport

due to its capacity advantages and cost efficiency. Container shipping enables large-scale movement of goods between continents, which would be impractical by road or rail alone.

In practice, global logistics operates as an integrated chain, where goods move between maritime, rail, and road transport before reaching their final destination. As a result, disruptions at any stage—such as port congestion or border delays—can affect the entire supply chain. In this context, TEN-T plays a key role by improving multimodal connectivity and ensuring that transport modes function as part of a coordinated system rather than isolated segments.

The following figure illustrates the distribution of freight transport across different modes

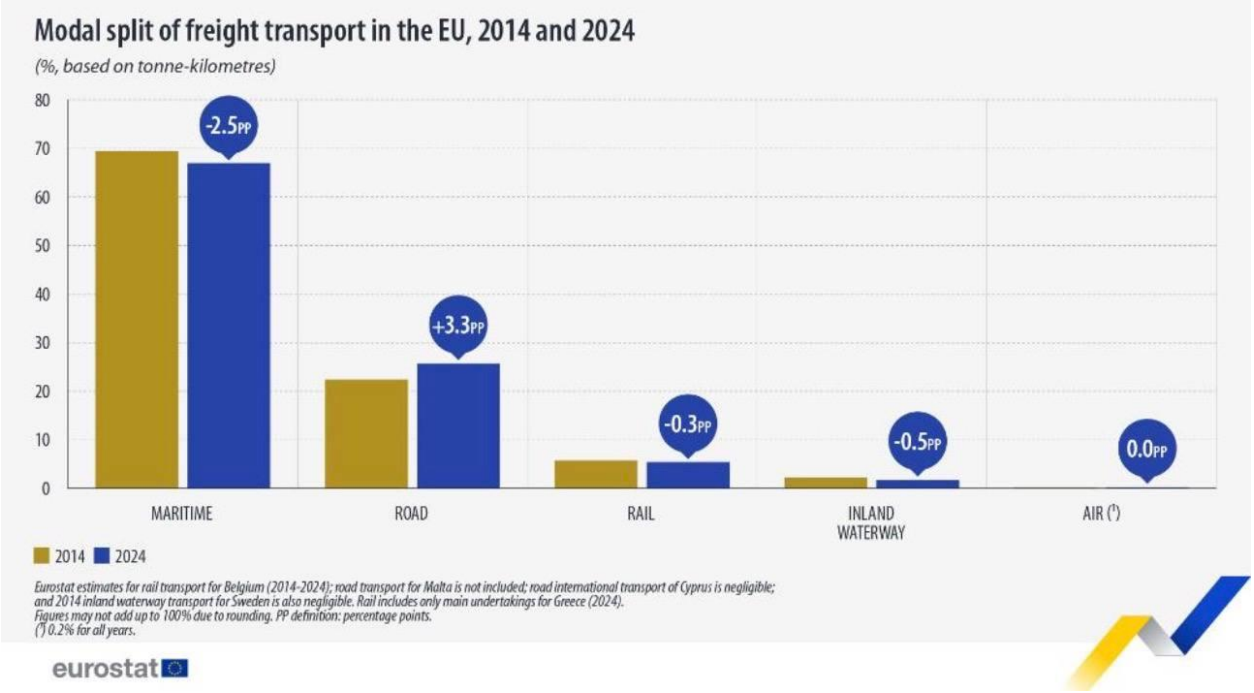


Figure 1. Distribution of freight transport by mode in the European Union (2014–2024)

The figure presents the distribution of freight transport connected to the EU, including both intra-EU movements and flows between the EU and the rest of the world, which helps explain the dominant role of long-distance transport in the overall system. Maritime transport accounts for the largest share throughout the period, decreasing slightly from around 70% in 2014 to approximately 67% in 2024, yet it remains the backbone of global trade due to its high capacity and cost efficiency over long distances. Road transport ranks second, increasing from roughly 23–24% to 26–27%, reflecting its continued importance in regional distribution, particularly for last-mile delivery and cross-border trade within Europe.

Rail transport and inland waterways represent smaller shares of total freight, with rail declining slightly from about 7% to 6% and inland waterways decreasing from around 4% to 3%. These lower shares can be partly explained by higher infrastructure costs and the

complexity of coordinating transport systems across multiple countries, indicating that even with investment, more sustainable transport modes face structural and operational limitations compared to the flexibility and speed of road transport. Air transport accounts for less than 1% of total freight, reflecting its limited role in freight logistics due to high costs despite its speed advantage.

Overall, the distribution shows a clear structure in which maritime transport dominates long-distance trade, while road transport remains essential within Europe, raising questions regarding the effectiveness of current transport investments in achieving a more balanced and efficient modal structure. Although rail currently plays a smaller role, its importance may increase as transport systems continue to develop, particularly within the framework of TEN-T and the broader transition toward more sustainable transport solutions.

Research Problem and Objectives

Despite long-term investment in the Trans-European Transport Network (TEN-T), estimated at several hundred billion euros (European Commission, 2021), freight transport within the European Union continues to face structural inefficiencies. Infrastructure quality remains uneven between Western and Eastern Europe, border crossings still generate delays, and differences in national regulations continue to complicate cross-border transport operations. These issues are not only theoretical but are reflected in performance data, where countries such as Germany and the Netherlands record Logistics Performance Index (LPI) scores above 4.0, while Romania and Bulgaria remain significantly lower (World Bank, 2023), indicating that transport efficiency within the EU is still strongly influenced by geography rather than system-wide uniformity.

At the same time, road transport continues to dominate inland freight, accounting for around 75% of total movement (Eurostat, 2023), despite TEN-T's objective to promote more balanced and efficient multimodal transport, including rail. This persistence suggests that large-scale infrastructure investment has not yet significantly transformed freight modal distribution. The limitations of the network are also visible along key corridors, such as the Rhine–Danube corridor, where cross-border sections still experience delays due to infrastructure mismatches and capacity constraints (European Commission, 2022). Furthermore, bottlenecks and missing links remain widespread across the network, meaning that well-developed sections are often constrained by weaker links elsewhere, reducing overall system performance.

Taken together, these observations indicate that investment alone does not guarantee transport efficiency, and that TEN-T's impact must be assessed through actual operational outcomes rather than planned objectives. This paper therefore addresses the research question: to what extent does TEN-T improve freight transport efficiency in the European Union? To answer this, the study examines the structure and scope of the TEN-T network, evaluates its impact on freight performance and trade flows, and identifies key limitations related to uneven development, regulatory fragmentation, and modal imbalance, along with potential directions for improvement.

2. Literature Review

Transport corridors are widely discussed in academic literature as an important factor in improving connectivity, trade, and regional development. Priemus and Zonneveld (2003), who focus on European spatial planning, describe corridors as structures that connect major economic centres and improve accessibility. Their idea is straightforward: when regions are better connected, they are more likely to participate in economic activity instead of remaining isolated.

A similar argument is made by Banister and Berechman (2001), well-known transport economists, who show that investment in infrastructure reduces transport costs and improves access to markets. This matters especially in the European Union, where the single market depends on goods moving smoothly across borders. Even small inefficiencies in transport can affect trade between countries.

However, later research makes it clear that infrastructure alone is not enough. Notteboom and Rodrigue (2005), widely recognised in the field of logistics and port development, argue that the key issue is integration. In practice, freight transport depends on how well ports, railways, and roads work together. If one part of the system is slow or poorly connected, it affects the entire supply chain.

This is supported by real data. The World Bank (2023), which regularly publishes global logistics indicators, shows that countries with better logistics systems tend to have higher levels of international trade. In other words, efficiency in transport is directly linked to economic performance.

The importance of integration is also highlighted in research on multimodal transport. Regmi and Hanaoka (2012), who study transport systems, show that combining different modes of transport improves efficiency by balancing cost, speed, and reliability. This is particularly relevant for large networks such as TEN-T, where goods rarely move using just one type of transport.

At the same time, the literature also points to clear limitations. According to the European Commission (2022), which is responsible for EU transport policy, the benefits of transport networks are not evenly distributed. Western European countries tend to benefit more due to stronger infrastructure and institutions, while Eastern European countries often face delays and lower investment levels. As a result, the system does not perform equally across the region.

Environmental concerns add another layer to the issue. The European Environment Agency (2021) highlights that transport corridors increase emissions and environmental pressure. Because of this, there is growing attention on shifting freight transport from road to more sustainable options such as rail and inland waterways. However, in reality, road transport still dominates because it is more flexible and easier to use.

Overall, the literature presents a balanced view. Transport corridors such as TEN-T clearly have the potential to improve efficiency and support economic integration. At the same time, their actual impact depends on how well different elements of the system work together, including infrastructure, coordination between countries, and the ability to integrate different transport modes into one functioning network.

3. Methodology

This study adopts a qualitative comparative approach based on secondary data from the European Commission (2022), the World Bank (2023), and Eurostat (2023). The analysis focuses on assessing the performance and impact of the Trans-European Transport Network (TEN-T) across EU member states through interpretation of existing statistical and institutional data.

The study uses the Logistics Performance Index (LPI) from the World Bank to compare logistics efficiency between countries and Eurostat data to examine freight transport modal distribution within the EU. In addition, European Commission TEN-T corridor reports are used to identify structural and operational differences across the transport network.

The analysis is conducted through cross-country comparison, focusing on differences between Western and Eastern Europe, infrastructure quality, and transport efficiency outcomes. No econometric or statistical modelling is applied.

Limitations include the use of secondary data, as LPI indicators partly rely on perception-based assessments, and EU corridor reports may reflect planned infrastructure rather than fully operational systems.

4. Analysis and Discussion

4.1 Structure and Geography of TEN-T

The Trans-European Transport Network (TEN-T) is structured into two main layers: the Core Network and the Comprehensive Network. The Core Network includes the most important routes and is prioritised for faster development, while the Comprehensive Network ensures that all regions of the European Union are connected, even if at a lower level of efficiency.

In reality, this creates a clear hierarchy. The Core Network is designed for speed, capacity, and international freight flows, while the Comprehensive Network focuses more on accessibility and regional inclusion.

Geographically, TEN-T is built around the main economic axis of Europe. Cities such as Paris, Berlin, and Rotterdam are not just connected — they act as central nodes where large volumes of goods are processed and redistributed. This means that the network is heavily concentrated around already developed regions.

At the same time, TEN-T is organised through several major corridors, such as the Rhine–Alpine Corridor, the North Sea–Baltic Corridor, and the Mediterranean Corridor. These corridors are designed to move freight across long distances efficiently by linking ports, industrial regions, and inland logistics

hubs.



Figure 2. Core TEN-T transport corridors in Europe
Source: European Commission

As shown in Figure 2, the network is not evenly developed. Western Europe has a dense and highly connected structure, where multiple routes overlap and provide alternative paths for freight. This reduces delays and increases reliability.

In contrast, parts of Eastern and Southeastern Europe have fewer connections and lower network density. In practical terms, this means fewer route options, higher dependency on single corridors, and a greater risk of delays when disruptions occur.

This uneven structure explains an important point: TEN-T works most effectively where infrastructure is already strong. In regions where connections are still developing, the network exists in theory but does not always function with the same level of efficiency.

4.2 Multimodal Transport and Logistics

Multimodal transport is often presented as one of the key achievements of the Trans-European Transport Network (TEN-T), appearing on paper as a well-coordinated system in

which each transport mode is used in the most efficient way. In reality, however, the system is less seamless, as freight within TEN-T does not move as one continuous flow but rather in stages—from ship to rail, and then from rail to truck—where each transition introduces a potential point of delay.

Each transfer requires time for unloading, handling, and reloading, meaning that even small disruptions can affect the entire logistics chain. At major ports such as Rotterdam, for example, rail departures operate on fixed schedules, and missing a slot can result in waiting times of several hours, demonstrating how an intended "efficient" system can, in practice, become slower than direct road transport.

This difference becomes even more evident across regions. As noted earlier, countries such as Germany and the Netherlands achieve higher logistics performance due to strong infrastructure and integration, reflected in LPI scores above 4.0 (World Bank, 2023), where connections are efficient and transfer processes are relatively smooth. In contrast, countries such as Romania and Bulgaria still face weaker rail connections, fewer logistics terminals, and persistent bottlenecks, with the European Commission (2022) highlighting ongoing technical and capacity constraints in cross-border rail sections, which increases delays and reduces reliability.

This is reflected in broader transport patterns, where road transport continues to dominate inland freight in the EU at around 75% (Eurostat, 2023), confirming that trucks remain the primary operational mode in practice. This dominance is also explained by economic and functional factors, as rail transport is most efficient over long distances and high volumes, while road transport offers greater flexibility and avoids transfer-related delays, making it more suitable for time-sensitive and shorter routes.

4.3 Economic Impact

TEN-T influences business operations within the European Union not in theoretical terms, but in practical, day-to-day logistics and production processes. Transport and logistics account for approximately 10–15% of total production costs, meaning that even marginal improvements in transport efficiency can translate into noticeable reductions in overall business expenditures.

A key effect of TEN-T is improved reliability. On major corridors such as Rhine–Alpine, increased capacity and reduced bottlenecks enhance transport stability and lower the risk of disruptions. When delivery times are predictable, firms are able to optimise production planning and maintain continuous operations, whereas uncertainty in transport leads to interruptions in production cycles. According to the European Commission, the removal of bottlenecks can reduce delays by up to 20–30%, resulting in more stable delivery performance and improved supply chain continuity.

This reliability has a direct cost implication. Uncertain transport conditions force companies to maintain higher inventory levels as a precaution against delays, which increases storage and capital costs. Inventory holding costs can reach 20–30% of inventory value annually; for instance, maintaining $1 million in inventory may generate $200,000–$300,000 in

annual holding expenses. Improvements in transport reliability reduce the need for such buffers, thereby releasing tied-up capital and improving financial efficiency.

TEN-T also strengthens market accessibility by improving connectivity between inland regions and major maritime gateways, reducing both transit time and uncertainty in international trade flows. Enhanced connections to North Sea ports, for example, enable firms in Central Europe to export goods more efficiently and with greater predictability. According to the World Bank, improved logistics performance can reduce trade costs by 10–15%, while even marginal improvements in logistics efficiency can lead to significant increases in trade volumes. Countries with higher logistics performance tend to engage in substantially greater trade activity, supporting business expansion and market integration.

However, these effects remain conditional on network completeness. The European Commission (2022) identifies persistent missing links and capacity constraints within parts of the TEN-T network. Even a single bottleneck can increase total transport time by 10–20%, reducing reliability and generating additional costs across the supply chain.

4.4 Logistics Performance (Comparative Data)

The Logistics Performance Index (LPI), developed by the World Bank, shows a clear gap between countries, and this gap reflects how transport systems actually work in real life, not just in theory (World Bank, 2023).

In reality, even one small delay can affect the whole system.

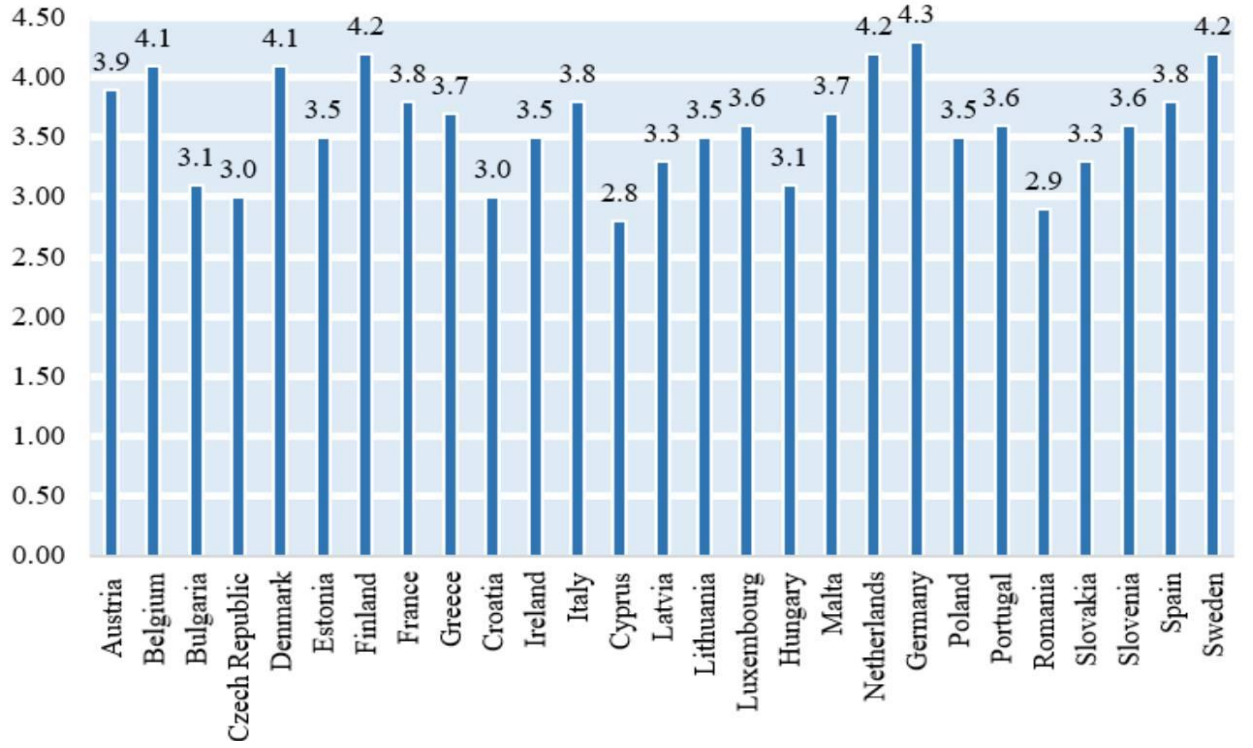


Figure 3. Logistics Performance Index (LPI) across European countries

Source: World Bank

Countries such as Germany and the Netherlands achieve LPI scores of around 4.2–4.3, reflecting logistics systems designed to maintain continuous freight movement with minimal interruptions across the transport chain (World Bank, 2023). In contrast, countries such as Romania, Bulgaria, and Croatia remain at 2.9–3.3, where delays are more frequent and form part of regular operational conditions. This difference primarily reflects variations in infrastructure capacity, coordination efficiency, and overall system organisation.

In high-performing countries, logistics infrastructure is designed to ensure uninterrupted flow. For example, the Port of Rotterdam, the largest port in Europe, handles over 14 million TEU annually (Port of Rotterdam Authority, 2023), supported by highly coordinated operations where cranes, trains, and trucks are scheduled in advance. As a result, containers can be transferred and forwarded within hours, with minimal waiting time between stages of transport.

In lower-performing systems, limited capacity and weaker coordination lead to significant delays at terminals and ports. Containers may remain in storage for 10–24 hours before further movement, slowing down the entire logistics chain and reducing overall efficiency. Similar patterns are observed in rail transport, where infrastructure differences further amplify performance gaps. Double-track and electrified lines can support continuous two-way traffic, while single-track systems require trains to wait for clearance, leading to delays of 20–30 minutes that accumulate along routes (European Commission, 2022).

Border operations also contribute to these differences. In efficient systems, crossings may take 15–30 minutes, whereas in less efficient systems they can take several hours due to higher traffic volumes, limited processing capacity, and administrative procedures. In addition, technical incompatibilities such as different signalling systems and electrification standards often require locomotive or driver changes, introducing additional delays of up to 1–2 hours per transition.

These structural differences are strongly linked to investment levels, as higher-performing countries invest significantly more per kilometre in transport infrastructure, resulting in greater capacity, better equipment, and more efficient operations (European Commission, 2022). Lower investment leads to bottlenecks and reduced system performance, which contributes to the observed LPI gap of approximately 1.0–1.3 points between countries (World Bank, 2023).

The impact of these differences is directly reflected in economic performance. Efficient systems enable faster delivery, lower inventory requirements, and more predictable supply chains, while less efficient systems require higher stock levels and increase operational costs due to uncertainty and delays (World Bank, 2023). Ultimately, the LPI differences illustrate not isolated weaknesses but fundamentally different levels of system integration and operational continuity across European logistics networks.

4.5 Case Example: Eastern Europe

The impact of TEN-T becomes particularly visible in Eastern Europe, where differences in investment levels and infrastructure quality produce sharply contrasting outcomes in practice. Poland stands as a clear example of successful integration into the TEN-T framework, having significantly expanded its rail and road corridors linking the country to Berlin and Western Europe, supported by more than €67 billion in EU funding between 2014 and 2020 (European Commission, 2021). This has translated into a noticeable acceleration of freight movement, with transit times reduced by approximately 20–30%, shortening journeys from around two days to roughly one and a half days, while Poland's exports increased by more than 80% between 2010 and 2022 (World Bank, 2023), showing how infrastructure development directly reshapes trade capacity.

A similar transformation is evident in the Port of Gdańsk, where container throughput expanded from approximately 0.5 million TEU to over 3 million TEU (Port of Gdańsk Authority, 2023), reflecting not only growth in scale but a fundamental shift in trade geography, as cargo is increasingly routed directly through Gdańsk instead of traditional Western European hubs, reducing both time and logistics costs. In contrast, this level of performance is not replicated across the region, as countries such as Romania and Bulgaria continue to face slower infrastructure development, lower investment levels, and sections of rail networks still operating on outdated systems (European Commission, 2022), resulting in reduced speeds and persistent inefficiencies across comparable distances.

These structural gaps are further reinforced by institutional and administrative constraints, where delays in project implementation caused by bureaucratic procedures and coordination challenges prevent infrastructure from translating into operational efficiency, even when physical networks exist. As a result, Poland is increasingly positioned as a regional logistics hub supporting redistribution and high trade volumes, while Romania and Bulgaria remain largely transit-oriented economies, characterized by higher delays and weaker logistical performance (World Bank, 2023).

The evidence ultimately shows that TEN-T does not automatically generate efficiency gains; rather, its impact is determined by the depth of investment, the quality of infrastructure, and the strength of institutional capacity, leading to fundamentally different outcomes across national contexts.

4.6 Regional Integration

TEN-T influences regional integration through concrete business decisions, as companies increasingly choose locations based on transport time, cost, and reliability, meaning that even small differences in delivery performance can determine where production facilities, warehouses, or distribution centres are established. A clear example is Volkswagen Group, which operates major production facilities in Poland and Central Europe supplying components across the EU, where automotive supply chains depend on just-in-time delivery and even short delays can disrupt production, while in large manufacturing plants stoppages can generate extremely high costs, which explains why firms prioritise locations connected to reliable transport corridors where delays are economically critical (European Commission, 2022).

A similar pattern is observed in e-commerce and logistics networks, where Amazon has developed large fulfilment centres in Poland, using the country as a distribution hub for European markets, enabling goods to reach major EU destinations within 1–2 days and allowing orders placed in countries such as Germany to be processed and delivered the next day, while longer or less predictable delivery times would require higher inventory levels across multiple locations and increase operational costs (World Bank, 2023), and DHL follows a comparable strategy by expanding logistics hubs along TEN-T corridors in Central Europe, where improved connectivity increases shipment turnover, reduces idle time, and enhances operational efficiency.

In contrast, weaker-connected regions such as Romania and Bulgaria experience more limited integration into these logistics networks, as infrastructure constraints and lower transport reliability increase delivery uncertainty, making just-in-time systems more difficult to implement and forcing firms to maintain higher inventory buffers, which raises storage costs and reduces the attractiveness of these locations for large-scale logistics investment, while these differences are reflected in broader economic outcomes where improved logistics performance can reduce trade costs by 10–15%, countries with stronger logistics systems trade significantly more, and inventory costs—often reaching 20–30% of inventory value annually—decline as delivery becomes more predictable (World Bank, 2023).

Regional integration under TEN-T is therefore strongly shaped by infrastructure quality, where well-connected regions attract investment and logistics activity due to higher efficiency and lower risk, while weaker-connected areas face higher costs, greater uncertainty, and reduced competitiveness.

5. Challenges and Opportunities

Despite its significant potential, the development of TEN-T faces several structural challenges that directly affect both the speed and effectiveness of network completion. The first constraint is financing, as large-scale infrastructure projects require extremely high investment and long implementation periods, which naturally slows progress. According to the European Commission, completing the core TEN-T network by 2030 requires over €500 billion in total investment (European Commission, 2022), while projects such as rail corridors and cross-border links often take 10–20 years to complete, meaning that funding gaps are persistent rather than temporary.

This financial pressure is closely linked to coordination problems, as TEN-T corridors cross multiple countries while transport systems remain nationally regulated, creating fragmentation in technical standards and administrative procedures. As a result, cross-border rail transport often requires changes in locomotives or drivers, adding 30–60 minutes or more per border crossing, which breaks continuity even in modern infrastructure and reduces system efficiency.

These challenges are intensified by uneven infrastructure development across Europe. While Western Europe operates dense, high-capacity networks, parts of Eastern and Southeastern Europe still face significant gaps that directly affect transport speed and reliability. In less developed corridors, freight trains may operate at 40–50 km/h, compared to 70–100

km/h in more advanced systems (European Commission, 2022), meaning that identical routes can take almost twice as long, increasing costs and reducing competitiveness.

At the same time, transport expansion places additional pressure on environmental sustainability, as the sector accounts for around 25% of total EU greenhouse gas emissions, with road transport as the main contributor (European Environment Agency, 2023). This creates a structural tension between infrastructure growth and climate objectives, especially if freight continues to rely heavily on road transport.

However, these constraints are matched by clear opportunities for transformation. Digitalisation offers the potential to reshape coordination across the network through real-time data, automation, and improved traffic management, reducing delays and increasing predictability. In parallel, modal shift policies provide a major opportunity to reduce environmental impact, as rail transport produces up to 70–80% less CO_2 per tonne-kilometre compared to road transport (European Commission, 2022), making it a strategic alternative for both efficiency and sustainability.

TEN-T also strengthens supply chain resilience, as demonstrated during recent global disruptions such as the COVID-19 pandemic, which exposed the vulnerability of fragmented logistics systems. A more integrated network enables rerouting and flexibility, reducing dependence on single corridors and improving stability under shock conditions. In addition, improved connectivity enhances the functioning of the internal market by enabling faster and more reliable cross-border trade, increasing competitiveness and supporting long-term economic growth.

6. Conclusion

The Trans-European Transport Network (TEN-T) represents a long-term structural transformation within the European Union, aiming not only to improve transport infrastructure but also to reshape how economic activity is organised across regions. The analysis shows that TEN-T has strengthened connectivity and supported the integration of European supply chains, enabling more efficient flows of goods and greater market access for firms. At the same time, its impact remains uneven, as differences in infrastructure quality, investment levels, and coordination continue to create performance gaps between regions. While TEN-T contributes to lower transport costs, improved logistics efficiency, and stronger economic integration, its full potential is limited by persistent structural and institutional constraints. Therefore, the effectiveness of TEN-T depends not only on infrastructure expansion, but also on achieving balanced development and ensuring that the network functions as a fully integrated system across all member states.

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