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TRANSPORT IN THE WESTERN MEDITERRANEAN FACING THE CLIMATE CRISIS: THE CHALLENGE OF TRANSITIONING TOWARDS A CLIMATE-RESILIENT TRANSPORT SYSTEM

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Medthink 5+5

The **MedThink 5+5** is a network of think tanks that encourages dialogue and research to promote regional integration in the Western Mediterranean, as a part of a wider Euro-Mediterranean region.

The network emerged in 2016 on the initiative of the IEMed in coordination with think tanks and public diplomacy institutions, building on a mandate from the Summit of Heads of State and Government of the 5+5 Dialogue in 2012. This unique platform, composed of more than 30 institutions from Portugal, Spain, France, Italy, Malta, Morocco, Mauritania, Algeria, Libya, and Tunisia, contributes to dialogue, exchange, and joint research on crucial sub-regional areas of cooperation.

Working to strengthen the Western Mediterranean Dialogue, the MedThink 5+5 offers the unparalleled possibility of increasing ownership of policy-making processes. It allows research institutions to transfer their messages to decision- and policymakers, while improving understanding of key challenges, needs and trends that have an impact on sub-regional cooperation.

POLICY STUDY

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The **European Institute of the Mediterranean** (IEMed), founded in 1989, is a think and do tank specialised in Euro-Mediterranean relations. It provides policy-oriented and evidence-based research underpinned by a genuine Euromed multidimensional and inclusive approach.

The aim of the IEMed, in accordance with the principles of the Euro-Mediterranean Partnership (EMP), the European Neighbourhood Policy (ENP) and the Union for the Mediterranean (UfM), is to stimulate reflection and action that contribute to mutual understanding, exchange and cooperation between the different Mediterranean countries, societies and cultures, and to promote the progressive construction of a space of peace and stability, shared prosperity and dialogue between cultures and civilisations in the Mediterranean.

The IEMed is a consortium comprising the Catalan Government, the Spanish Ministry of Foreign Affairs and Cooperation, the European Union and Barcelona City Council. It also incorporates civil society through its Board of Trustees and its Advisory Council.

The **Centre for Transportation Studies for the Western Mediterranean** (CETMO) is an independent non-partisan think tank and non-profit international cooperation organisation, established in 1985 under the auspices of the United Nations, with the objective of supporting socio-economic development through progress in transport and logistics, especially in the Western Mediterranean.

The CETMO aims at developing regional cooperation at both institutional and technical levels in order to facilitate international transport conditions throughout the Mediterranean and the Western Mediterranean in particular, due to its belonging, participation, and collaboration with an extensive network of organisations facilitating Mediterranean cooperation. The CETMO also provides policy makers, transport infrastructure managers and operators with practical and innovative analysis and knowledge.

The **Group of Transport Ministers for the Western Mediterranean** (GTMO) is an informal cooperation group composed by the Transport Ministers of the region to promote dialogue and cooperation for the development of transport and to contribute to the Euro-Mediterranean partnership. It was created in 1995 with the support of the ministries of transport of Algeria, Spain, France, Italy, Morocco and Tunisia and it joined the cooperation framework of the 5+5 Dialogue in 2007 with the full participation of all its member countries: Algeria, France, Italy, Libya, Malta, Mauritania, Morocco, Portugal, Spain, and Tunisia.

The rotating presidency of the group is renewed approximately every two years at a transport ministerial conference, which also serves to define the strategic guidelines of the new presidency and its work programme. The strategic guidelines are developed by the GTMO5+5 expert group, which includes senior officials from member countries and observer organisations and meets regularly twice a year. The activities in the work programme typically focus on monitoring and analysing the region's transport networks and their operation, as well as analysing trends and challenges in the sector, in addition to exchanging best practices and generating and disseminating knowledge for the benefit of the region and its stakeholders.

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FOREWORD

Senén Florensa
Executive President, IEMed

Pere Padrosa
President, CETMO

Ahead of the 11th Conference of Ministers in charge of transport in the Western Mediterranean countries (to be held in Rabat on 24 June 2026), and following the transfer of the Presidency from the Republic of Malta to the Kingdom of Morocco, the European Institute of the Mediterranean (IEMed) and the Centre for Transportation Studies for the Western Mediterranean (CETMO) have launched a Policy Study on transport in this region. The study explores climate resilience in a sector increasingly exposed to climate-related disruptions, examining both the vulnerabilities facing transport systems and the strategies needed to strengthen their capacity to adapt and thrive in an era of growing uncertainty.

Bringing together the perspectives of eight experts, the Policy Study offers a multidisciplinary assessment of the challenges confronting the transport sector across the Western Mediterranean. It examines the implications of climate change and geopolitical instability, the opportunities and risks associated with emerging technologies and low-carbon energy sources, and the financial mechanisms required to support adaptation and resilience-building.

The study opens with an overview by Imed Zammit of the principal climate related challenges facing maritime transport in the Western Mediterranean. Building on this foundation, Sergi Saurí provides an in-depth analysis of how climate change and geopolitical tensions are reshaping transport planning, management, and logistics across the region.

Attention then turns to the emerging dependencies of a Mediterranean in transition. In her contribution, Nora Aboushady examines the evolving role of alternative energy sources and technological innovation, highlighting their importance for enhancing both the sustainability and resilience of regional transport systems. These themes are further developed by Jérôme Verny and Ouail Oulmakki, who focus on the strategic role of ports as critical nodes in the transport network. Through the cases of the ports of Barcelona and Tanger Med, they explore how infrastructure, innovation, and governance can contribute to greater resilience in the face of mounting environmental and economic pressures.

The final section of the study addresses one of the most pressing challenges for the sector: financing adaptation. Juan Alario and Joan Alario examine the state of adaptation finance in the Western Mediterranean, drawing attention to the limited number of countries that have adopted dedicated adaptation plans for the transport sector and the resulting implications for resilience. The study concludes with a contribution from Andrea Tinagli, who maps the current financial architecture for climate adaptation and outlines how governments, financial institutions, and other stakeholders can better mobilise and leverage available instruments to support the transformation of transport systems in the region.

Taken together, the contributions provide a comprehensive overview of the risks, opportunities, and policy priorities shaping the future of transport in the Western Mediterranean. At a time when climate impacts are becoming more frequent and severe, the study underscores the need for coordinated regional action to build transport systems that are not only more sustainable, but also more resilient, adaptive, and prepared for the challenges ahead.

Across the various contributions, a recurring theme is the need to better account for the structural asymmetries that exist

between the northern and southern shores of the Western Mediterranean. Differences in resources, infrastructure, technological capabilities, institutional capacity, and access to finance shape both the vulnerabilities and the opportunities facing transport systems across the region. The authors argue that these asymmetries must be explicitly considered in policy design and implementation to ensure that the transition towards a low-carbon and climate resilient transport sector benefits all 5+5 countries. A more balanced and inclusive regional approach will be critical to fostering cooperation, strengthening resilience, and ensuring that no country of the 5+5 is left behind in the transition of the transport sector.

Maritime Transport Facing Climate Change in the Western Mediterranean

Imed Zammit
Consultant, Transport & Logistics at SRDB Consulting

Introduction

The Western Mediterranean is currently one of the most strategic and yet most vulnerable maritime regions in the world. Located at the crossroads of major routes linking Europe, Africa, and Asia, it concentrates a significant share of international maritime trade, energy flows, and passenger transport. However, this economic centrality is accompanied by increasing environmental pressure in a semi-enclosed basin that is particularly sensitive to climate change.

Recent scientific observations confirm that the Mediterranean is warming faster than the global average (Copernicus Climate Change Service, 2025; IPCC, 2023). According to data from the European Copernicus programme, regional temperatures have already increased by approximately +1.54°C compared to pre-industrial levels, while Mediterranean Sea surface temperatures are rising at a faster rate than those of the open oceans.

Marine heatwaves, prolonged droughts, and extreme weather events are becoming more frequent and more intense, progressively altering navigation conditions and the operation of port infrastructures. In this context, maritime transport occupies a paradoxical position (UNCTAD, 2024; IMO, 2023). On the one hand, it remains essential to the functioning of Mediterranean economies and to the development of Euro-Mediterranean trade. On the other, it contributes to global warming through its emissions of greenhouse gases (GHGs) and atmospheric pollutants. At the global scale, the maritime sector accounts for approximately 3% of global CO_2 emissions, while in the Western Mediterranean, the high concentration of traffic intensifies environmental and health impacts, particularly in major port areas and densely used shipping corridors.

The Mediterranean region thus appears as a true laboratory for the transition of maritime transport (REMPEC, 2024; European Union, 2023a, 2023b). Ports, shipping companies, and public authorities must simultaneously address the intensification of climate risks, the growing international regulatory requirements, and the need to decarbonise maritime activities. The entry into force of the Mediterranean Sulphur Emission Control Area (Med SOx ECA) in May 2025, the progressive integration of maritime transport into the European Union Emissions Trading System (EU ETS), as well as the carbon neutrality targets set by the International Maritime Organization (IMO), illustrate the scale of this transformation.

From this perspective, this article offers an analysis of the interactions between maritime transport and climate change in the Western Mediterranean. After examining the strategic importance of regional maritime traffic and its environmental footprint, the study will analyse the impacts of climate change on maritime and port activities. It will then explore ongoing regulatory and technological transformations, before identifying the main adaptation and resilience strategies for stakeholders in the Mediterranean maritime sector.

Climate, maritime transport and coastal areas in the Mediterranean

The Mediterranean is now considered one of the world's major climate hotspots. Its semi-enclosed configuration, limited water exchange, and the intensity of human activities make it a region

particularly vulnerable to climate disruption. In July 2025, the average sea surface temperature reached a record level of 26.9°C, with local anomalies exceeding +5°C in certain areas of the Gulf of Lion and the Ligurian Sea. This accumulation of heat promotes the development of prolonged marine heatwaves, the frequency of which has increased fourfold since the 1980s.

Table 1. Main climate indicators in the Western Mediterranean

Indicator	Observed/projected values	Source
Mediterranean temperature increase	+1.54 °C vs pre-industrial era	Copernicus
Warming of sea waters	+0.4 °C per decade	Plan Bleu
Record sea surface temperature (2025)	26.9 °C	Copernicus
Increase in marine heatwaves	X4 since 1980	IPCC
Projected sea level rise	Up to 80 cm by 2100	IPCC

Source: Compiled by the author

Regional climate projections are particularly concerning (IPCC, 2023; UNEP, 2023). According to IPCC scenarios, temperature increases could exceed +3°C by the end of the century in some Mediterranean regions. At the same time, sea level rise could reach nearly 80 cm by 2100, significantly increasing the risks of coastal flooding and shoreline erosion.

The Western Mediterranean is one of the world's main maritime corridors, linking the Atlantic to Europe, the Middle East, and Asia via the Strait of Gibraltar and the Suez Canal (UNCTAD, 2024). Approximately 20% of global maritime trade passes through the Mediterranean. Regional maritime traffic is characterised by strong diversity. Containerised flows play a central role, supported by the development of global supply chains and transshipment hubs. Ports such as Tanger Med, Barcelona, Marseille-Fos, and Valencia play a structuring role in Euro-Mediterranean and intercontinental trade. Roll-on/roll-off (Ro-Ro) and passenger traffic also constitute an essential segment of exchanges between the two shores of the Mediterranean, particularly through the ports of La Goulette, Genoa, and Algiers. However, this economic centrality is accompanied by significant environmental pressure. The high density of maritime traffic in a semi-enclosed basin leads to a high concentration of atmospheric emissions and increases the ecological vulnerability of the Mediterranean Sea basin.

Maritime transport is currently a major source of atmospheric pollutants (IMO, 2023; UNCTAD, 2024). At the global scale, the sector accounts for approximately 2.5 to 3% of global CO_2 emissions.

Table 2. Main pollutants from maritime transport

Pollutant	Main Source	Environmental Impact
Carbon dioxide (CO_2)	Combustion of fossil fuels	Climate warming
Sulphur oxides (SO_x)	Heavy fuel oil	Atmospheric pollution, acid rain
Nitrogen oxides (NO_x)	Marine engines	Tropospheric ozone
Fine particulate matter (PM2.5)	Maritime combustion	Health impacts
Methane (CH4)	Liquefied Natural Gas (methane slip)	High global warming potential

Source: Compiled by the author

Beyond CO_2, maritime transport generates significant emissions of sulphur oxides (SO_x), nitrogen oxides (NO_x), and fine particulate matter ($PM_{2.5}$) (Ledoux et al., 2021; Sofiev et al., 2018). These pollutants directly affect air quality in port areas and densely populated coastal regions.

The Strait of Gibraltar is one of the main emissions hotspots due to the intensity of traffic connecting the Atlantic and the Mediterranean. Major port cities such as Marseille, Barcelona, and Valencia also experience significant health impacts linked to ship emissions. Maritime activities also contribute to the degradation of Mediterranean marine ecosystems. Ocean acidification, pollutant discharges, and rising temperatures are weakening essential ecosystems such as seagrass meadows (Posidonia oceanica) (Litzi-Misan et al., 2023).

The Mediterranean maritime sector is not only a contributor to climate change, it is also directly affected by its consequences. The intensification of extreme weather events is increasingly disrupting maritime operations. Medicanes, marine storms, and heavy swells lead to port call delays, temporary terminal closures, and changes in shipping routes. Mediterranean ports are among the most vulnerable infrastructures (World Bank Report, 2021). Sea level rise increases the risks of inundation, flooding of quays, and coastal infrastructure erosion. Heatwaves also affect port equipment and working conditions for staff. Extreme temperatures increase the energy demand of infrastructure and accelerate the deterioration of installations.

In addition, Mediterranean maritime transport is currently evolving in a context marked by the convergence of climate and geopolitical crises (UNCTAD, 2024). Tensions in the Red Sea since 2023 have significantly disrupted shipping routes linking Europe and Asia via the Suez Canal. Many vessels have been forced to reroute around the Cape of Good Hope, substantially increasing voyage distances, logistics costs, and GHG emissions. These disruptions have strengthened the strategic role of several Western Mediterranean ports, notably Tanger Med, Barcelona, and Marsaxlokk, which have recorded a significant increase in transshipment activity.

Table 3. Main ports of the western Mediterranean and climate vulnerabilities

Port	Main Activity	Main Climate Risks	Adaptation Measures
Marseille-Fos	Freight and passengers	Extreme mistral winds	Reinforcement of breakwaters
Barcelona	Cruise and container traffic	Heatwaves, drought	Shore power electrification (cold ironing)
Valencia	Container hub	Coastal erosion, heatwaves	Energy transition measures
Tanger Med	Transshipment	Storms, congestion	Logistics modernisation
La Goulette/ Rades	Passengers and Ro-Ro traffic	Coastal erosion, flooding and medicanes	Resilience assessment studies
Genoa	Freight and passengers	Flooding, extreme waves	Port reconfiguration

Source: Compiled by the author

Table 4. Maritime climate regulatory timeline

Year	Regulation	Expected impact
2024	Extension of EU ETS to shipping	Progressive CO2 pricing
2025	Entry into force of Med Sox ECA	Reduction of Sox and PM 2x5 emissions
2025	Fuel EU Maritime	Promotion of alternative fuels
2027	IMO global GHG taxation	Accelerated decarbonisation
2030	IMO -20% target	Energy transition
2050	IMO carbon neutrality target	Net-zero emissions

Source: Compiled by the author

Table 5. Comparison of alternative maritime fuels

Carburant	Advantages	Limitations
LNG	Reduction of Sox and particulate emissions	Methane slip (methane leakage)
Green methanol	Easier storage	High cost
Green hydrogen	Zero direct emissions	Limited infrastructure
Green ammonia	Long-term potential	Toxicity and high cost
Biofuels	Compatibility with existing fleet	Limited availability

Source: Compiled by the author

Responses, transition and governance: decarbonisation, adaptation and regional cooperation

In response to the climate emergency, international organisations and European institutions have initiated a profound regulatory transformation of maritime transport. The entry into force of the Mediterranean Sulphur Emission Control Area (Med SOx ECA) on 1 May 2025 is a major milestone (REMPEC, 2024; IMO, 2023). This regulatory evolution is accelerating the transition toward alternative fuels (European Union, 2023a, 2023b).

In response to these transformations, stakeholders in Mediterranean maritime transport must develop multidimensional adaptation strategies (IMO, 2023). In the short term, the priority concerns regulatory compliance and climate risk management. Shipping companies must adapt their fleets to new environmental standards, improve their energy efficiency, and strengthen their systems for managing weather-related disruptions. Over the medium term, investments in alternative fuels, shore side electrification, and resilient port infrastructure are becoming essential. In the long term, the transition toward green shipping corridors and the growing role of renewable energy could profoundly transform the economic geography of the Mediterranean basin. Digitalisation is also a major adaptation lever. The use of artificial intelligence-based route optimisation systems, the integration of real-time oceanographic and meteorological data, and the energy monitoring of vessels are progressively becoming standard practices in the maritime market.

The adaptation of maritime transport to climate change in the Western Mediterranean cannot be addressed solely at the national level. The transboundary nature of shipping routes, atmospheric emissions, and climate risks requires a regional approach based on Mediterranean cooperation. Within this framework, several regional initiatives play a structuring role. The WestMED initiative, supported by the EU, promotes the development of a sustainable blue economy through the strengthening of maritime cooperation between countries on both shores of the

Western Mediterranean. Issues related to the decarbonisation of maritime transport, port resilience, and the development of blue skills are now among the priorities of this regional cooperation.

At the same time, European energy transition policies strongly influence Mediterranean dynamics. The European Green Deal, the FuelEU Maritime strategy, and the EU's climate financing mechanisms encourage investment in sustainable port infrastructure, shore-side electrification, and alternative fuels. However, these transformations also raise issues of equity and integration for Southern Mediterranean countries, whose financial, institutional, and technological capacities remain more limited.

One of the main challenges for the countries of the southern Western Mediterranean lies in strengthening their legal and regulatory frameworks in order to ensure better compliance with international standards related to the protection of the marine environment and the decarbonisation of maritime transport. Although most Mediterranean states are parties to the main international maritime conventions adopted under the auspices of the IMO, significant gaps remain between the ratification of legal instruments and their effective implementation. Conventions relating to the prevention of marine pollution, the reduction of atmospheric emissions, and the energy efficiency of ships require substantial administrative, technical and institutional capacities.

In this context, strengthening the enforcement of international conventions such as MARPOL, the London Convention, the Ballast Water Management (BWM) Convention, as well as instruments related to GHGs, appears as a strategic priority for the countries of the southern Western Mediterranean. The effective implementation of these conventions requires, in particular, the adaptation of national legislation, the development of Port State Control mechanisms, and the strengthening of monitoring, reporting and verification (MRV) systems for maritime emissions.

Regional frameworks also play a key role in this dynamic. The Barcelona Convention and its protocols constitute one of the main environmental governance instruments in the Mediterranean today. Strengthening their implementation could help harmonise maritime environmental policies across the entire Mediterranean basin, particularly in terms of pollution prevention, coastal ecosystem protection, and the climate adaptation of port infrastructure.

The development of more integrated maritime governance also requires better coordination between maritime administrations, port authorities, environmental agencies, and private sector stakeholders in the maritime industry. In several Southern Mediterranean countries, significant institutional challenges remain, particularly in relation to environmental control of ships, port waste management, and monitoring compliance with new international climate requirements.

Beyond the legal framework, the success of the maritime transition in the Western Mediterranean largely depends on strengthening the human, technical, and institutional capacities of the countries in the region. The growing requirements linked to the decarbonisation of maritime transport call for new skills in a range of fields: ship energy management, alternative fuels, emissions monitoring, port resilience, marine meteorology, cybersecurity of port infrastructure, and the digitalisation of logistics operations.

In the countries of the southern Western Mediterranean, needs in training and technical assistance remain particularly significant. The development of maritime and port skills therefore constitutes a strategic lever to ensure an inclusive transition and to prevent the widening of technological gaps between the two shores of the Mediterranean.

Several regional and international organisations already play a major role in this field, including the IMO, the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), the EU, the World Bank, and regional maritime cooperation initiatives such as WestMED. Training programmes, exchanges of expertise, green port pilot projects, and technology transfer mechanisms are essential tools to support Mediterranean states in implementing new environmental regulations.

Capacity-building must also target port authorities and maritime administrations responsible for enforcing international conventions. Strengthening port inspections, developing environmental monitoring laboratories, integrating digital maritime surveillance tools, and modernising information systems are key priority areas. Furthermore, maritime universities, naval academies, and regional training centres could play a decisive role in the development of new skills related to the sustainable blue economy and the energy transition of the maritime sector. The creation of regional training and applied research networks would help strengthen scientific and technical cooperation among Mediterranean countries.

Regional cooperation therefore appears essential in order to avoid the emergence of a two-speed maritime transition between the northern and southern shores of the Mediterranean basin. The development of green corridors, the pooling of alternative fuel bunkering infrastructure, the sharing of climate data, and the training of human resources are strategic levers to strengthen the collective resilience of the Mediterranean maritime system.

From this perspective, North African ports could play an increasingly important role in the regional energy transition. Indeed, these countries possess significant strategic potential thanks to their solar and wind resources. Tunisia, Morocco and Algeria could become major producers of green hydrogen and regional bunkering hubs for alternative fuels. Thanks to their proximity to major shipping corridors and their renewable energy production potential, they possess significant advantages to become next-generation logistics and energy platforms. This development could help strengthen regional economic integration while supporting international objectives for the decarbonisation of maritime transport.

Conclusion

The Western Mediterranean is currently at the intersection of three major transformations: climate change, the energy transition, and the geopolitical reconfiguration of global trade. The accelerated warming of the Mediterranean, sea level rise, and the increasing frequency of extreme weather events are already affecting navigation conditions, maritime safety, and the resilience of port infrastructure (IPCC, 2023; UNEP, 2023). In this context, adapting Mediterranean maritime transport is no longer an option but a strategic necessity. Actors capable of anticipating regulatory, technological, and climate-related changes will hold a major competitive advantage in the Mediterranean basin of the future.

Recommendations

In the face of increasing climate risks in the Western Mediterranean, a regional maritime transition strategy must be based on cooperation, resilience, and decarbonisation. In this regard, it is recommended to establish Euro-Mediterranean working platforms, drawing on the expertise of specialised organisations such as the IMO, the REMPEC, and the Union for the Mediterranean (UfM). At the same time, climate risk assessments and emissions reduction targets should be systematically integrated into national maritime transport strategies, supported by measurable indicators to ensure effective monitoring and implementation. The resilience of port infrastructure should be strengthened through targeted investments in coastal protection measures, early warning systems, and resilient energy infrastructure and equipment. At the same time, the decarbonisation of maritime transport should be accelerated through the development of alternative fuels, shore-side electrification, improvements in vessel energy efficiency, and the digitalisation of port operations. To reduce asymmetries between the shores, it is necessary to mobilise dedicated financial instruments, encourage technology transfer, and strengthen institutional capacities. Finally, integrating climate, energy, and digital dimensions into maritime curricula is essential to train the skills required for a just and sustainable transition.

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Resilient Transport Infrastructure in the Western Mediterranean under Climate and Geopolitical Uncertainty

Sergi Saurí
Deputy President, CETMO.
Associate Professor at UPC-BarcelonaTEch and Director of CENIT at CIMNE.

Introduction

Freight and passenger transport are one of the cornerstones underpinning the development of countries, particularly those most exposed to globalisation. Logistics chains are highly demanding in terms of cost and reliability; therefore, any disruption to operations may result in significant economic losses and even the loss of markets. The effects of climate change and the disruption of trade flows arising from geopolitical tensions have a substantial and direct impact not only on the transport sector itself, but also on the wider economy through their indirect consequences. In recent years, the Western Mediterranean has not been immune to these disruptions.

This article examines the impacts of climate change and geopolitical tensions on transport management and planning. To this end, the paper is structured into seven sections. The first provides a brief overview of the region's main maritime flows and logistics corridors, while the second identifies the principal vulnerabilities of the transport system. Sections 4 and 5 describe strategies and measures aimed at reducing these risks. Sections 6 and 7 provide main conclusions and the recommendations, respectively.

The region's role in international trade: a macro perspective

Broadly speaking, and focusing on maritime transport, which accounts for 80% of international trade flows (UNCTAD, 2023), the first defining characteristic of the region is the asymmetry of north-south flows. According to Selfa (2024), between 2017 and 2022, cargo transported from the European countries of the Western Mediterranean to the Maghreb ranged between 30.9 and 40.1 million tonnes, whereas flows in the opposite direction ranged from 63 to 40.8 million tonnes. This is mainly explained by the weight of bulk energy products. Excluding these products, however, the situation is reversed. In 2022, for example, 15 million tonnes were transported from European ports to the southern shore, while flows in the opposite direction amounted to 8.6 million tonnes. Overall, the Maghreb is primarily an exporter of raw materials and energy, characterised by large cargo volumes, whereas southern Europe mainly exports finished goods with lower volumes but higher added value.

At the global level, a significant share of worldwide container traffic - around 10% (24.2 million TEUs in 2022, according to UNCTAD) - corresponds to the Asia-Europe route, which under normal circumstances passes through the Suez Canal. A substantial part of this traffic transits through the Western Mediterranean. These flows are highly exposed to geopolitical tensions in the Middle East, as evidenced during 2024 and early 2025 by the disruptions in the Red Sea, when traffic through the Suez Canal declined by between 40% and 60%.

With regard to the main transport infrastructure supply, on the southern shore it is possible to identify a set of strategic infrastructures connecting Mauritania, Morocco, Algeria, Tunisia and Libya. Together, they form an infrastructure axis enabling the interconnection of the main socioeconomic development areas of the Maghreb countries, which could be referred to as the Trans-Maghreb Multimodal Corridor (TMC). Although still largely an emerging initiative, the existing infrastructure already constitutes the initial framework of what is intended to become a high-performance

corridor, with the broader ambition of evolving into an economic and trade corridor between these countries. Beyond its role as a regional connector, it also has the potential to become a key gateway linking Europe and Sub-Saharan Africa.

At present, the corridor comprises a combination of linear infrastructures (roads and railways) and nodal infrastructures (ports, airports and logistics platforms) that channel the region's most significant transport flows. The corridor encompasses 66% of the population, 70% of the urban surface area and 66% of the industrial activity of the Central Maghreb. Its main operational limitation remains the discontinuity between Algeria and Morocco, which prevents it from functioning as a fully integrated corridor along its entire length.

On the European side of the Western Mediterranean, the main infrastructures structuring economic and trade networks are defined within the Trans-European Transport Network (TEN-T). This network consists of infrastructures promoted by the European Union (EU) to improve connectivity between member states in the fields of transport, energy and telecommunications, including roads, railway lines, maritime ports, airports, inland waterways and logistics platforms. Among the priorities of the new Connecting Europe Facility (CEF) programme (2021-2027) are high-speed rail, transport decarbonisation, strengthening infrastructure resilience to climate-related crises - the capacity of infrastructure to withstand, adapt to, and recover from the adverse impacts of climate change - , and military mobility. Within the regional context, particular relevance should be given to the Mediterranean Corridor, which connects southern Spain with northern Europe by rail.

Strains on the transport system: the impacts of climate change and the geopolitical landscape

Transport infrastructure in the Western Mediterranean has not been immune to the geopolitical tensions and climate change impacts affecting the global context. In recent years, several examples have clearly illustrated these challenges.

With regard to climate change, a first factor is temperature rise. According to Cramer et al. (2019), average annual temperatures are already 1.5°C higher than during the pre-industrial period (1880-1899), with projections indicating an increase to 2.2°C by 2040 if no mitigation measures are implemented. In a similar way, IPCC (2023) stated that it is very likely that warming will exceed 1.5°C during the 21st century. Rising temperatures accelerate the deterioration of roads, railway lines and airport runways, for instance through pavement degradation, rail buckling and track misalignment. This results in higher maintenance costs, increased operational risks and more frequent service disruptions. A clear example can be found in the extreme heatwaves recorded in southern Europe and North Africa, particularly during 2022 and 2023, which placed considerable pressure on transport infrastructure. Temperatures exceeding 40-45°C caused rail deformation (track buckling) and damage to road surfaces (Cramer et al., 2019; OECD, 2024).

A second expected climate-related impact in the Western Mediterranean concerns changes in precipitation patterns (Cramer et al., 2019). The region is shifting from historically high spatial and temporal variability towards a marked trend of declining rainfall. Indeed, both the frequency and severity

of droughts have increased significantly since 1950. For every one-degree increase in average temperature, the probability of rainfall in the region is projected to decline by approximately 4%. Droughts may reduce the operability of inland waterways, although these currently play only a limited role within the region. More broadly, droughts may also reduce agricultural production, thereby increasing the strategic importance of transport systems in ensuring food supply security.

In addition, forest fires and extreme weather events have increasingly disrupted transport corridors, generating delays and damage across European transport networks. Climate change is contributing to both the growing frequency and severity of extreme events (OECD, 2024). Recent extreme weather events in Morocco, for example, have directly affected both maritime and land transport infrastructure. Heavy rainfall and flash floods damaged roads and disrupted inland transport routes, particularly in coastal areas such as Safi, where access roads were temporarily blocked. At the same time, severe storms and heavy swells forced temporary closures and operational disruptions at major ports, including the Ports of Casablanca and Tanger Med, resulting in vessel delays, cargo congestion and ships remaining at anchorage due to unsafe operating conditions. These events also affected rail and road connectivity, highlighting how extreme weather phenomena can simultaneously disrupt port operations and inland logistics networks across North Africa.

A third climate-related factor affecting transport systems is sea-level rise. According to the 2023 Synthesis Report of the International Governmental Panel on Climate Change (IPCC), the average rate of sea level rise between 1901 and 1973 was of 1.3 mm per year, 1.9 mm per year between 1971 and 2006, and 3.7mm per year between 2006 and 2018. This trend may directly affect infrastructure located along coastlines and has important implications for future infrastructure design and adaptation strategies.

Turning to geopolitical tensions, it should first be noted that a substantial share of international maritime trade connects Asia and Europe through two principal routes: the shortest route via the Suez Canal and the alternative route around the Cape of Good Hope. Any disruption to these flows has direct consequences for ports across the Western Mediterranean region, in addition to the impacts arising from intra-regional tensions.

For instance, since late 2023, attacks on commercial vessels in the Red Sea associated with the Houthi conflict have disrupted traffic through the Suez Canal, a route that normally accounts for approximately 12-15% of global trade. By early 2024, container traffic through Suez had declined by between 40% and 60%, with many vessels rerouted around the Cape of Good Hope, adding between 10 and 15 days to transit times and increasing maritime freight rates by two to three times on certain routes. The impacts on ports have been uneven. Ports located in the Western Mediterranean experienced traffic growth, including the Ports of Algeciras, Valencia and Barcelona, whereas ports in the Eastern Mediterranean, such as Piraeus, Port Said and Gioia Tauro, experienced delays, traffic reductions and changes in shipping itineraries. This situation generated cascading effects across both maritime and inland logistics chains in Europe and North Africa (UNCTAD, 2024).

Another example of an intra-regional geopolitical disruption occurred in 2021. Diplomatic tensions between Algeria and Spain led to the closure of the Maghreb-Europe gas pipeline, which had previously

transported substantial volumes of natural gas to Europe. As a consequence, Algeria redirected exports through alternative infrastructure, including the Medgaz pipeline and increased shipments of liquefied natural gas (LNG) by sea. This required the deployment of additional LNG carriers and contributed to rising maritime transport costs and increased logistical complexity (Marwa Rashad et al., 2021).

The direct and indirect economic and human consequences of these disruptions have been substantial. According to the OECD (2024), economic losses associated with natural disasters increased from $198 billion in the 1970s to $1.6 trillion during the 2010s.

The challenge of reducing the climate vulnerability of the transportation system

Two main strategies can be distinguished in addressing climate change. The first is an adaptation strategy, aimed at increasing resilience - understood as the capacity of a system to recover functionality after a disruption - and reducing the vulnerabilities of the transport system to disruptive events. The second is a mitigation strategy, implemented ex ante, which in the context of climate change focuses primarily on decarbonisation and improvements in energy efficiency.

There are two key regional particularities that condition the definition and implementation of measures aimed at reducing transport vulnerability. First, the two shores of the Mediterranean are separated by the external border of the EU, which may generate a range of border effects. This has implications for climate-related regulatory measures and increases the difficulty of coordinating climate policies across the region. Second, economic realities across the region are highly diverse and economic interests are not always aligned. This complicates the implementation of joint regional strategies and results in differing levels of governmental capacity to respond to disruptions.

Several initiatives are currently being implemented to decarbonise the transport and mobility sector across the region, although with significant asymmetries in both their intensity and geographical scope. On the one hand, there is the case of the EU. As an important step towards achieving these objectives, the European Commission published on 14 July 2021 the anticipated “Fit for 55” legislative package, comprising around a dozen new and revised legislative proposals across multiple areas (energy efficiency, renewable energy, transport, emissions trading and reduction, among others), with the aim of achieving a 55% reduction in CO_2 emissions by 2030 compared with 1990 levels. In the same month, the EU issued several communications specifically related to maritime transport, including:

- **COM (2021) 550:** the “Fit for 55 Package”, a set of proposals aimed at delivering the objectives of the European Green Deal;
- **COM (2021) 551:** the revision of the EU ETS Directive to progressively include emissions from maritime transport;
- **COM (2021) 562:** the FuelEU Maritime proposal, which limits the greenhouse gas intensity of maritime fuels (grams of CO equivalent per MJ) through reductions relative to a reference value; and

- **COM (2021) 563:** the proposed revision of the Energy Taxation Directive (ETD), aimed at reinforcing the objectives of FuelEU Maritime.

Among this package of measures, particular attention should be given to the EU ETS Directive, which has been fully implemented – in the previous year only a portion of the ETS was applied – since the beginning of this year, both because of its significance for the maritime sector and because of its asymmetric impacts within the Mediterranean region. The measure establishes that vessels with a gross tonnage (GT) above 5,000 must account for emissions when allowances apply to intra-EU voyages (100% of emissions), return voyages to or from EU ports (50% of emissions), and emissions generated while berthed at EU ports (100%). For example, a vessel sailing from Singapore to Algeciras would be required to pay for 50% of the emissions generated during that voyage.

This creates clear incentives for shipping companies to use North African ports as transhipment or intermediate calls prior to entering the EU, thereby shortening the voyage leg immediately preceding arrival at an EU port and consequently reducing ETS-related costs. This is a clear example of an unintended distortion generated by an environmental policy as a consequence of the European border effect within the Mediterranean. The International Maritime Organization (IMO) could potentially play an important role in harmonising decarbonisation measures within the maritime sector. However, the current inability to advance towards the implementation of a global ETS scheme does not suggest an encouraging outlook in this regard, at least in the short term.

On the other hand, North African countries - particularly Morocco, Algeria and Tunisia - are also making efforts to decarbonise the transport sector, although at varying levels of ambition and implementation capacity. Morocco is promoting an ambitious decarbonisation strategy based on the progressive electrification of mobility, the deployment of renewable energy sources, and the development of green hydrogen. In addition, the country aims to position itself as a regional hub for green hydrogen and clean fuels, both for domestic use and for export to Europe (World Bank Group, 2022). In Algeria, the strategy is more strongly focused on railway and port modernisation - including the construction of new railway lines and port expansion projects - as well as on improving national logistics connectivity in order to reduce dependence on heavy road transport (OECD, 2025). Tunisia, with more limited investment capacity, is prioritising sustainable urban mobility, particularly through tramway systems, electric public transport and improvements in urban energy efficiency (OECD, 2025).

The EU border effect within the Mediterranean cannot be ignored in transport decarbonisation policies, particularly those affecting international transport. Addressing these challenges requires enhanced regional dialogue and coordination.

Beyond mitigation, building a more resilient transport system requires a redefinition of the way in which infrastructure has traditionally been planned, designed, constructed and managed. According to the World Bank (2025), this transformation can be structured around five fundamental pillars: transport and mobility planning and financing; infrastructure engineering and design; operation and maintenance; contingency planning; and institutional and coordination capacity.

From a financial perspective, developing more resilient infrastructure entails addi-

tional upfront costs. However, when assessed over the long term, these costs are expected to be offset by subsequent benefits, including lower maintenance expenditures and reduced risk exposure. According to the OECD (2024), every dollar invested in resilience generates four dollars in benefits.

In several countries across the region, the need to increase resilience capacity is compounded by existing infrastructure deficits and insufficient transport provision. Public-private partnerships may therefore constitute an important mechanism for addressing these investment requirements (see paper 7 of this Policy Study). In addition, nature-based solutions (NBS) – measures aimed at protecting, restoring and sustainably managing natural systems by harnessing nature's functions (e.g., planting trees to absorb carbon dioxide from the atmosphere through photosynthesis) - are gaining increasing relevance in enhancing resilience, particularly due to their cost-effectiveness.

At the same time, infrastructure resilience requires stronger coordination among stakeholders and the establishment of multi-level governance frameworks (see paper 4 of this Policy Study). However, the current governance model for infrastructure asset management across the region remains far from this objective. This challenge is further exacerbated by limited intergovernmental coordination within countries, where administrations and public departments often continue to operate in institutional silos.

With regard to resilience policies, Morocco is strengthening the adaptation of infrastructure to floods and extreme climate events. The country has developed advanced risk management and financing mechanisms, such as the Fund to Combat the Effects of Natural Disasters (FLCN), as well as insurance schemes against catastrophic events. Morocco is also promoting early warning systems, nature-based solutions, and enhanced territorial and urban coordination in order to protect roads, coastal areas and strategic logistics corridors (World Bank Group, 2022).

In Tunisia, the priority lies in protecting urban transport systems against increasingly severe flooding events. The country is expanding internationally financed urban resilience programmes aimed at strengthening drainage systems, road infrastructure and hydrometeorological systems in vulnerable areas.

Algeria is focusing its efforts on the modernisation of railway and port infrastructure, as well as on improving territorial connectivity in order to reduce vulnerabilities to extreme events. Although institutional progress has been slower, the country participates in regional Mediterranean cooperation initiatives related to climate adaptation in the transport sector.

In Libya, infrastructure adaptation to climate change is in a critical state due to political fragmentation and the lack of a unified national budget. Current actions remain limited and heavily dependent on international cooperation, and very focused on water security (UNDP, 2026a).

Infrastructure adaptation to climate change in Mauritania is conditioned by severe desertification in the country's interior and the vulnerability of its coastal areas to sea-level rise, particularly in its capital, Nouakchott. Although the country possesses an active climate governance framework (UNDP, 2026b), its actions are strictly dependent on external funding. Currently, these measures focus on constructing rural hydraulic infrastructure for rainwater harvesting, preserving dunes as natural coastal

defences, and implementing a collaborative Multi-Hazard Early Warning System (UNDRR & UNIDO, 2026).

And, finally, Europe is promoting several measures aimed at strengthening the resilience of transport infrastructure to climate change, particularly within the Mediterranean region. The EU considers the adaptation of roads, railways, ports and airports to extreme climate events to be a strategic priority. Among the main European initiatives are the development of new climate adaptation strategies under the European Green Deal (EGD) framework developed in 2019. The EU has also adopted specific regulations and programmes to ensure that infrastructure systems are more resilient and capable of operating during future climate crises. These include, for example, Directive (EU) 2022/2557 on the resilience of critical entities, the Connecting Europe Facility (CEF) Regulation 2021–2027, and the Technical Guidance on Climate Proofing of Infrastructure (2021-2027).

Resilience in the current geopolitical context

The resilience of transport systems to disruptions arising from geopolitical tensions requires a somewhat different approach from that applied to climate change. Whereas the latter is generally framed in terms of mitigation and risk, the central issue here lies in the balance between security and resilience: security against deliberate actions targeting transport assets, and resilience as the capacity to recover from disruptions such as traffic rerouting, deliberate attacks, cyberattacks and other destabilising events.

The implications of designing and managing infrastructure that is better prepared for geopolitical disruptions are broadly similar to those associated with climate adaptation, although focused on a different set of threats and disruptions. As in the case of climate resilience, this may require additional investment, but such costs can be offset through reduced operational risks during the infrastructure lifecycle.

Likewise, measures aimed at strengthening institutional and stakeholder coordination, contingency planning, operation and maintenance are equally applicable to geopolitical disruptions, with the ultimate objective of building resilient logistics chains. According to Sheffi (2007), this resilience capacity is based on five pillars: interconnectedness, flexibility, redundancy, collaboration, and a culture of resilience. In practical terms, this may translate into the availability of alternative ports for maritime routes, as well as enhanced coordination and communication among supranational stakeholders.

From an infrastructure supply perspective, these pillars imply:

1. The provision of services capable of adapting to changing customer and market needs;

2. Investments aimed at increasing capacity beyond normal demand requirements in order to absorb potential additional traffic during disruptions. Significant investments are currently being undertaken in several Maghreb ports to develop new deep-sea terminals and improve cargo handling processes. Clear examples include Tanger Med in Morocco, as well as Cherchell and Djen Djen in Algeria, and Enfidha in Tunisia (Selfa, 2024);

3. Cooperation among logistics service providers to facilitate an interconnected regional service offering. This requires both institutional coordination and oper-

ational cooperation among regional transport and logistics stakeholders; and

4. The planning and development of transport infrastructure and services as part of an integrated and regionally interconnected network.

Institutional and business cooperation across the region therefore emerges as a fundamental prerequisite for making these four dimensions achievable.

In addition, the need for greater interconnectedness, flexibility and redundancy also implies enhanced connectivity between the northern and southern shores of the region - or example, through maritime services and the development of the Strait of Gibraltar rail node, as well as further development of the Trans-Maghreb Corridor. On the European side, the new Connecting Europe Facility (CEF) programme seeks to strengthen resilience, particularly within the context of military mobility, although from an essentially European perspective.

The current situation remains far from optimal. Economic realities differ significantly across countries, particularly on the southern shore of the Mediterranean. Greater cooperation is therefore required at all levels, including between the European Commission and the countries of the Southern Mediterranean. To date, resilience strategies have largely been planned and developed at national level in the southern countries and at European level in the north, without any comprehensive or integrated vision for the Western Mediterranean as a whole.

Conclusion

The Western Mediterranean will be one of the regions where the effects of climate change are expected to be felt most acutely, with significant implications for the operation and performance of transport infrastructure. This is particularly relevant in a region through which approximately 10% of global maritime traffic passes.

Countries across the region are implementing transport decarbonisation measures, although with highly asymmetric levels of ambition and capacity. Moreover, the fact that the region constitutes part of the EU's external border generates inefficiencies in certain policies, as illustrated by the case of the EU ETS.

Recommendations

Based on the analysis presented in this document, two main recommendations emerge. First, to effectively implement decarbonisation measures in international trade - such as the extension of the ETS to maritime transport - and to mitigate cross-border spillover effects, enhanced regional coordination is essential. And, second, climate change and the impacts of geopolitical tensions, both international and intra-regional, clearly highlight the need to strengthen the resilience of transport infrastructure. In this context, adequate financing mechanisms and enhanced regional coordination will constitute two fundamental pillars for addressing future challenges.

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Climate, Energy and Transport: Emerging Dependencies in a Mediterranean in Transition

Nora Aboushady
Associate Professor of Economics, Cairo University and Associate Researcher, German Institute of Development and Sustainability (IDOS)

Introduction

In an increasingly interconnected global trade system, climate shocks are severely damaging transport routes, disrupting supply chains and people's mobility, and transmitting these effects to domestic economies and potentially to regional and international markets. At the same time, transport is one of the main drivers of climate change. Due to its heavy reliance on fossil fuels, it accounts for nearly 25% of total global greenhouse gas emissions (ITF, 2024).

Although the Mediterranean basin accounts for only about 6% of global carbon emissions (Moncada et al., 2024), it remains one of the most vulnerable regions to climate change. With its densely populated coastal areas and critical role in global supply chains, the impacts of climate change can be particularly severe. These challenges highlight the need for proactive climate mitigation measures and strengthened resilience to climate shocks through tailored adaptation strategies.

Against this backdrop, cooperation in climate mitigation and adaptation has become a policy priority for the Western Mediterranean. Given the region's importance as a strategic global and regional trade corridor, improving connectivity is essential; however, doing so in the context of climate change requires collective action. As a result, growing attention is being directed toward transforming the transport sector by developing more sustainable and climate-resilient systems.

Two key policy actions can support this transition: (1) expanding the deployment of renewable energy and (2) promoting technological innovation. Integrating these two actions into the transport sector can enhance its sustainability, efficiency, and resilience to climate shocks. On the northern shore of the Western Mediterranean, the overarching framework for climate transition is provided by European Union (EU) regulations, coupled with transport-specific policy frameworks and domestic policies. On the southern shore, countries operate under separate domestic policy frameworks and generally face more limited financial, technical, and governance capacities, creating a transition gap between the two groups of countries.

Therefore, examining the complex interplay between climate risks and the prospects for building an interconnected, sustainable, and resilient transport sector is essential. This paper focuses on recent developments in energy sources and technological innovations that serve the dual objectives of sustainability and resilience. It then reviews recent developments in these areas in the Western Mediterranean. It also discusses major opportunities arising from enhanced connectivity in the region, as well as risks associated with increased regional interconnectedness. The study concludes with policy recommendations aimed at building a stronger and more sustainable transport sector in the region.

Recent technological developments and implications for a sustainable and resilient transport sector

The transport sector contributes nearly 25% of global greenhouse gas emissions (ITF, 2024). Road transport remains the largest source of transport-related emissions, both globally and in the Western Mediterranean. In the southern countries of the region, emissions from road transport are expected to continue rising

due to rapid population growth, accelerated urbanisation, and increasing reliance on private vehicles. Meanwhile, maritime shipping accounts for approximately 2% of global greenhouse gas emissions (Hoffmann, 2021), while the aviation sector contributes about 14% of global carbon emissions (Dos Reis, 2021).

Rising emissions from the transport sector increase the risk of both acute and chronic climate impacts. While acute climate shocks can destroy road and port infrastructure and disrupt supply chains, slower long-term climate change has cumulative effects that also lead to infrastructure degradation, operational disruptions, and substantial maintenance and repair costs (ITF, 2024).

It is therefore urgent to take decisive steps toward the transition of the transport sector into a carbon-neutral and climate-resilient system. Two complementary actions are required for this transition: climate mitigation measures to reduce the transport sector's contribution to climate change, and climate adaptation measures to enhance its ability to respond to and recover from climate shocks. In general, there is a lack of balance between efforts dedicated to mitigation and adaptation in the transport sector, as adaptation measures are often more difficult to implement (Clemente, 2024). However, recent developments in renewable energy, technologies and artificial intelligence (AI), as well as investments in infrastructure and energy corridors, can support both mitigation and adaptation in the transport sector, potentially generating a double-win outcome. The focus in this section is on electrification, hydrogen and synthetic fuels, infrastructure, and digitalisation and AI.

In the area of climate mitigation, electrification is increasingly seen as an effective solution for decarbonising light-duty vehicles. The global market for electric vehicles (EVs) continues to expand rapidly, supported by falling battery costs and the expansion of charging infrastructure. Advances in lithium-ion battery technology are improving vehicle range and gradually enabling shorter recharging times (Raimondi & Noussan, 2024). Electrification is also transforming rail transport and is being increasingly integrated into operations and auxiliary services in the maritime and aviation sectors (Agostinelli et al., 2022; Mead, 2021). It also offers significant potential to reduce emissions in long-distance transport, particularly if improvements in charging technologies extend the operational range of regional buses and long-haul trucks (Mead, 2021). From a climate adaptation perspective, electrification enhances the resilience of transport systems by reducing reliance on fossil fuels. This, in turn, lowers the sector's vulnerability to climate shocks and associated fuel supply chain disruptions.

Decarbonising hard-to-abate transport segments remains challenging, as full decarbonisation is not yet economically viable at scale. In recent years, hydrogen and synthetic fuels have gained increasing attention as promising alternatives to conventional fuels in maritime transport, aviation, and heavy-duty freight, where direct electrification remains technically or economically constrained (Kochanek et al., 2025).

Hydrogen offers several technical advantages that support its integration into sustainable transport systems. It can be produced from renewable energy sources (green hydrogen), making it possible to generate it in many locations worldwide. This reduces dependence on global fuel markets and enhances resilience to potential supply disruptions. It can also be produced from natural gas combined with

carbon capture and storage (CCS), offering a lower-carbon alternative to conventional hydrogen production pathways. When used in fuel cells, its by-products are water and heat, with no direct emissions of carbon dioxide (Rodés, 2021). In addition, hydrogen can be stored and transported in derivative forms such as ammonia and methanol, enabling the geographic separation of production and consumption. This feature is particularly important for the development of sustainable regional energy value chains across the Western Mediterranean, where existing gas infrastructure linking North Africa and Europe could be partially repurposed to transport hydrogen or its derivatives.

In addition, the decarbonisation of the transport sector will require substantial infrastructure investments. In the maritime sector, port infrastructure investments are critical for improving connectivity and supporting the decarbonisation of shipping. Ports are increasingly evolving into multifunctional energy hubs that integrate a wide range of activities, including the production, storage, use, distribution, and export of clean energy carriers such as hydrogen and renewable electricity.

Ports offer a strategic advantage because they can co-locate energy production and consumption. Many ports - particularly in the Southern Mediterranean - are located in areas with high solar irradiation and, in some cases, access to wind and tidal resources (Agostinelli et al., 2022). This geographic positioning enables renewable energy to be generated onshore and used directly to power port operations (so-called Onshore Power Supply) and to supply low-carbon fuels to vessels (Barbiere & Capoani, 2025), which is expected to reduce greenhouse gas emissions from shipping by at least 50% by 2050 (D'Alfonso, 2021). This transformation, however, requires significant upgrades to existing port infrastructure to support the storage and handling of alternative fuels. At the same time, restructuring ports as energy hubs can also strengthen transport resilience. By developing multifunctional hubs that provide the production, storage, and distribution of renewable energy, services can be restored more quickly after natural disasters, as reliance on long and potentially disrupted fuel supply routes is reduced.

Digitalisation and AI are key drivers of the climate-energy-transport nexus. The COVID-19 pandemic accelerated digital transformation to maintain supply chain sustainability, resilience, and efficiency. Digital technologies play a dual role in the transport sector's transition. On the one hand, they contribute to climate mitigation by digitalising emission-intensive processes. The digitalisation of cross-border trade procedures is also an effective trade facilitation measure that saves time and reduces transport congestion (Hoffmann, 2022), leading to lower emissions. On the other hand, digitalisation strengthens transport system resilience by enabling efficient information systems and well-designed communication strategies during climate-related shocks.

Moreover, the use of AI has enhanced the ability to generate detailed insights into the impacts of climate change on transport infrastructure through digital models (so-called digital twins), which are fed by data from sensors embedded across transport assets. This can help assess vulnerabilities and enable predictive maintenance to avoid disruptions in a timely manner. It also allows the simulation and forecasting of natural disasters, supporting proactive and preventive measures. Overall, this improves the resilience of transport systems by enhancing preparedness for climate shocks that can cause damage or disruption (ITF, 2024; D'Alfonso, 2021).

Digitalisation also supports better integration across transport modes, enabling more efficient multimodal systems (Ortiz, 2022). Finally, it improves the efficiency of transport services. Technologies such as 5G, blockchain, and Information of Things (IoT) are increasingly being integrated into transport and logistics to optimise freight flows and improve port operations (Barbiere & Capoani, 2025). AI further enhances transport network management through large-scale data collection, analytics, and information exchange among stakeholders along supply chains (Rodes, 2021; ITF, 2024).

Building sustainable transport in the Western Mediterranean: recent developments and emerging trends

The Mediterranean reflects a transition gap between its northern and southern shores. On the northern shore, the overarching framework for climate transition is provided by EU regulations, including (1) the EU Climate Target Plan, which aims to reduce net greenhouse gas emissions by at least 55% by 2030, (2) the European Climate Law, which sets the objective of achieving climate neutrality by 2050, and (3) the New EU Strategy on Climate Adaptation, which seeks to build a climate-resilient society by 2050. Transport-specific frameworks, such as the Connecting Europe Facility and the Trans-European Transport Network (TEN-T), further address both mitigation and adaptation challenges. On the southern shore, countries operate under separate domestic policy frameworks and generally face more limited financial, technical, and governance capacities.

In Northern Mediterranean countries, electric vehicle adoption has accelerated alongside the widespread installation of charging stations across European roads. By 2030, most vehicles are expected to be zero- or low-emission, while public transport is set to be enhanced through automated systems. By 2050, nearly all vehicles are projected to be zero-emission. The Trans-European Transport Network (TEN-T) is also being upgraded to support sustainable transport (European Commission, 2021).

In the maritime sector, the FuelEU Maritime Initiative aims to shift toward clean fuels in order to reduce greenhouse gas emissions from vessels above 5,000 gross tonnes (Panaro & Buonfanti, 2024). As previously noted, decarbonising the hardest-to-abate transport segments will require time before hydrogen becomes technologically and economically viable at scale. Nevertheless, countries in the region, including Italy, Spain and France, are investing in port infrastructure to support the greening of maritime transport. Major ports such as the Port of Algeciras and the Port of Marseille are developing hydrogen infrastructure that not only supports the decarbonisation of shipping but also positions these hubs as strategic nodes for hydrogen trade between Africa and Europe. Furthermore, the EU regulation on developing a European rail network for competitive freight requires EU countries to promote intermodality between rail and other transport modes (D'Alfonso, 2021), which is critical for reducing emissions and improving both the efficiency and resilience of the transport sector.

Energy corridors linking both shores of the Mediterranean are also strategic enablers of the transition in the transport sector. By facilitating the trade of renewable electricity and hydrogen, they can accelerate the decarbonisation of transport in the northern

region by providing access to competitively priced energy from the South. One of the most promising pathways involves repurposing existing trans-Mediterranean natural gas pipelines to transport hydrogen. This approach could substantially reduce infrastructure costs and accelerate the development of integrated regional hydrogen markets. Furthermore, European companies and investors have already launched several pilot projects across the Southern Mediterranean. These initiatives aim to produce green and blue hydrogen for export to Europe.

In this context, Italy is investing in pipelines connecting North Africa - particularly Algeria - with Europe to secure gas supplies, with the long-term objective of repurposing parts of this infrastructure for hydrogen transport in the future (Aboushady & Faus Onbargi, 2023). Furthermore, the EU Global Gateway initiative includes a range of projects designed to enhance regional connectivity and improve energy security and supply chain sustainability. One of the most important cross-regional projects is the Global Maritime Green Corridor, which is planned to produce 6 million tonnes of green methanol annually to supply the maritime sector (Furness, 2024). Another project is the ELMED interconnector, a high-voltage submarine electricity cable between Italy and Tunisia, which is expected to reduce carbon emissions by more than 200 tonnes per year and support the deployment of renewables in Tunisia. The South H2 Corridor is expected to transport hydrogen from Tunisia to Europe and is planned to become operational by 2030. In Morocco, another project is underway under the Global Gateway, aimed at supporting regulatory reforms in the electricity market to strengthen integration with the EU market.[1]

On the other hand, countries on the Southern Mediterranean shore operate under separate policy frameworks with varying implementation. In general, multimodal connectivity remains limited, transport systems are heavily reliant on road transport, and the regional port system is fragmented. In 2014, the GTMO 5+5 multimodal network was approved, covering the main nodes of economic activity across the ten participating countries. Within this framework, the Trans-Maghreb Multimodal Corridor is planned to extend along the coastal line from Mauritania to Libya and include motorway and railway corridors, ports, airports, and multimodal logistics platforms (Boira & Berzi, 2021). However, the development of this network - adapted from the TEN-T model - continues to face significant challenges due to fragmented transport infrastructure in parts of the region, particularly in Libya and Mauritania, as well as weak integration with maritime transport systems. The project has also been constrained by limited coordination between countries and low levels of regional trade integration, which reduce incentives for investment in shared transport infrastructure.

Furthermore, Southern Mediterranean countries are lagging behind in renewable energy development. In the case of Libya, political instability has become a quasi-structural feature, undermining prospects for long-term energy diversification and transport decarbonisation strategies. In Algeria, the transport sector still relies heavily on fossil fuels, with the energy mix dominated by this category. Moreover, more than 93% of transport energy consumption is concentrated in road transport (Chettah & Ammar, 2021), with significant adverse environmental implications.

[1] https://north-africa-middle-east-gulf.ec.europa.eu/document/download/b848ea64-2b33-420b-a16a-3500c9fae06f_en?filename=PartIII%20SOUTH.pdf

Algeria and Tunisia have both launched hydrogen strategies, but progress in this area remains relatively slow. Mauritania adopted its Hydrogen Roadmap in 2021 and has a small but growing number of solar, hydrogen, and green ammonia projects in partnership with the EU. In contrast, Morocco stands out as a hub for renewable energy generation and exports, as well as green hydrogen development, positioning itself as a regional model for energy transition. According to the latest available data on hydrogen production projects, Morocco hosts 21 projects, including green hydrogen production, solar energy, and green ammonia initiatives.[2] The government has also set one of the region's most ambitious energy targets, aiming to generate 52% of installed electricity capacity from renewable sources and to reduce greenhouse gas emissions by 42% by 2030, including an unconditional reduction target of 17 per cent (IEA, 2019).

With regard to the electrification of transport, Morocco is one of the fastest-growing EV markets in the region. It is also among the main manufacturing hubs for EV batteries in Africa, owing to its strong integration into automotive value chains, its proximity to European markets, and its access to critical raw materials (GIZ, 2024). Additionally, more than half of the Moroccan railway network is electrified (Hammami, 2024). As one of the African countries with the highest liner shipping connectivity (Hoffmann, 2021), Morocco has also worked to improve the efficiency and resilience of its ports by integrating renewable energy into transport infrastructure, particularly through the development of facilities such as the state-of-the-art Tanger Med port, the largest in the region. Morocco has further invested in digitalising cross-border maritime procedures and has been advancing the implementation of a smart port programme (Lhamouz, 2021). Furthermore, Morocco has developed one of the most modern rail networks in Africa and is the first country on the continent to operate a high-speed rail service - Al Boraq. In addition, the Tangier-Lagouira line runs from Tanger Med port along the Atlantic coast to the Mauritanian border and is intended to establish a high-speed commercial transport corridor linking the Western Mediterranean shores to West Africa (Hammami, 2024).

Sustainable transport in the 5+5 region: fostering deeper integration or creating critical dependencies?

The global economy is undergoing structural shifts towards regional value chains and production networks. In response to global shocks - including pandemics, geopolitical tensions, and climate-related disruptions - industrialised countries are increasingly nearshoring investments and diversifying suppliers. These evolving global supply chain configurations open a window of opportunity for the Mediterranean basin to achieve deeper and more sustainable economic integration.

Investing in clean energy and advanced technologies enables the development of sustainable, smart, and climate-resilient transport systems in the region. This supports multiple objectives, including deeper regional integration through the smoother flow of goods, services, energy, and people, while also addressing climate risks

[2] Hydrogen Production Projects Interactive Map, International Energy Agency, available online: https://www.iea.org/data-and-statistics/data-tools/hydrogen-production-projects-interactive-map

that increasingly threaten the region. It further strengthens the geopolitical relevance of Western Mediterranean countries as a key hub in global energy and transport networks. At the same time, these developments may also generate new dependencies that risk creating tensions or undermining transition efforts.

The creation of a sustainable and resilient transport sector in the region will require two major transitions in the southern part of the Western Mediterranean: the energy transition and the digital transition. For Europe, there is a risk that reducing dependency on Russian gas could be replaced by growing energy dependencies on southern partners. Net energy importing countries in the South may reduce their dependence on global fossil fuel markets by developing renewable energy and hydrogen and eventually integrating these into transport systems and other hard-to-abate sectors. However, this transition will require increasing technological dependence on the northern shore of the Mediterranean. It also demands large-scale infrastructure and connectivity investments, which are highly capital-intensive. Given budget constraints in the South, much of this investment will rely on international financial institutions, EU funding, and private sector participation. This may further deepen financial dependencies and external funding reliance. Both technological and financial dependencies are therefore likely to complicate cooperation dynamics in the region.

Hydrogen illustrates well the scale and complexity of these investment requirements across the entire value chain. This begins with the development of renewable power generation facilities - such as solar and wind farms - that supply electricity to electrolysers, which use this electricity to split water into hydrogen and oxygen. In water-scarce regions, large-scale hydrogen production will also require significant investment in desalination infrastructure. Transmission networks are needed to deliver renewable electricity to electrolysers, alongside investments in storage systems, pipelines, port terminals, and export facilities. For countries in the Southern Mediterranean, the costs of decarbonisation may not be the primary priority, as they face more immediate challenges related to climate change impacts, particularly in agriculture and food security. As a result, these multiple transitions may not fully materialise, potentially widening the gap between both shores.

Digitalisation also presents a major challenge for Southern Mediterranean countries. Although it offers significant opportunities to improve efficiency and sustainability in the transport sector, these countries continue to lag behind in digital adoption. Digital innovation and advanced technologies remain concentrated in the northern shore. These asymmetries risk creating new vulnerabilities in the South, increasing dependence on the North in areas such as advanced technologies, cybersecurity, and data governance. As a result, sustainability transitions may also generate digital dependencies, raising concerns about autonomy and potentially widening the technological gap between both shores, thereby limiting the transformative potential of the transition in Southern Mediterranean countries.

The integration of clean energy and transport systems in the Western Mediterranean can help countries position themselves as energy hubs or transport gateways, thereby enhancing their geopolitical influence. For example, Morocco's role as a renewable energy exporter and Spain's position as a European entry point for African energy illustrate shifting regional dynamics. However, shared infrastructure

- including energy corridors and transport networks - can also increase mutual exposure to shocks, as disruptions in one part of the system may generate cascading effects across the network. These interdependencies may also create geopolitical vulnerabilities and increase the risk of tensions over infrastructure control and resource governance in the region. Furthermore, the dual transition (energy and digital) will generate increased demand for critical minerals that are not fully available within the region. These new demand dynamics may heighten the Western Mediterranean's exposure to global market shocks due to reliance on external supplies of critical raw materials. Finally, the transition also carries the risk of stranded assets in resource-rich southern countries, particularly Algeria and Libya, which could generate adverse political and socioeconomic consequences and ultimately undermine transition efforts.

The way forward

The Western Mediterranean is at the forefront of a transformative shift driven by climate change, the energy transition, and the evolution of transport systems. The region stands at a critical juncture: while the transition toward sustainable and resilient energy and transport systems creates new opportunities for cooperation, innovation, deeper regional integration, and sustainable growth, it also introduces significant technical, economic, and geopolitical challenges that must be carefully managed. Successfully steering the energy, digital and transport transitions will require substantial efforts in policy coordination, strategic investment, and sustained political commitment. To effectively manage these processes, the following policy recommendations are proposed:

Introduce integrated policy frameworks: Countries on the southern shore should adopt integrated policy frameworks that reflect the strong interlinkages between climate, energy, investment, and transport policies. Transport decarbonisation, for example, will depend on reforms of the energy sector, including regulatory harmonisation with partner countries to enable the development of cross-border energy corridors, the gradual phase-out of fossil fuel subsidies to support market integration, and the establishment of clear renewable energy targets to accelerate deployment, e.g., electrification in relevant transport segments. Beyond sector-specific measures, horizontal policies are equally important. Investment frameworks should enhance transparency, strengthen governance and the business environment, improve access to finance, and provide targeted incentives to attract both domestic and foreign investment in sustainable infrastructure.

Strengthen South-South connectivity: The 5+5 framework should be further leveraged to promote cooperation in building sustainable and resilient transport systems across the southern region. Greater emphasis should be placed on fully operationalising the Trans-Maghreb Multimodal Corridor as a key backbone of regional connectivity. This includes expanding rail freight corridors and improving cross-border interoperability, and strengthening port-rail-road logistics integration. Developing multimodal transport systems is essential, as they improve logistics efficiency and support climate mitigation by reducing congestion and emissions from the over-reliance on road transport. They also enhance resilience by enabling rerouting options that help bypass chokepoints, particularly in areas affected by climate shocks or infrastructure disruptions.

Leverage EU frameworks to invest in sustainable infrastructure: The new Pact for the Mediterranean, launched in

2025 and currently under implementation through its Action Plan, can serve as a key instrument to deepen cooperation in the Western Mediterranean. Within this framework, the EU Global Gateway initiative can mobilise additional resources to finance investments in sustainable infrastructure, renewable energy systems, and cross-border connectivity. These investments can play a role in reducing infrastructure gaps, strengthening regional integration, and accelerating the deployment of low-carbon transport solutions.

Prioritise just transitions within and between countries: It is essential for Europe to recognise that climate risks extend beyond its own borders and to demonstrate a strong commitment to a just transition in neighbouring countries. Northern partners in the Western Mediterranean should avoid reinforcing a model of clean energy export enclaves in the South that primarily serve Europe's transport and energy transition while leaving local development needs behind. A just transition requires targeted financial support to close existing gaps in finance, technology and governance capacity between both shores. It also demands sustained investment in skills development and capacity-building to ensure that the necessary technical and institutional expertise is available across the southern region. In addition, 5+5 partners should design policies that explicitly address the social consequences of both the digital and energy transitions required for sustainable transport systems. For instance, the energy transition may lead to job losses in fossil fuel-dependent sectors, particularly in resource-rich countries, resulting in significant adjustment costs. Similarly, digitalisation and automation may replace labour in certain transport and logistics functions. As a result, the transition in the Southern Mediterranean must be accompanied by comprehensive policies that address not only environmental objectives, but also social inclusion, ensuring that sustainability gains are fairly shared.

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Western Mediterranean Ports at the Nexus of Operational Sustainability, Digital Transformation, and Energy Innovation

Jérôme Verny
Professor, NEOMA Business School

Ouail Oulmakki
President, Ethica-Chain Association

Literature review

A literature structured around three major axes

Research on Mediterranean ports has, in recent years, been organised around three relatively distinct axes. A first body of work documents the physical, operational, and governance constraints that characterise the region. Studies show that, with the exception of major hubs such as Valencia or Gioia Tauro, most Mediterranean ports suffer from limited capacity, institutional fragmentation, and modest levels of automation, resulting in container dwell times above global standards (Mollaoğlu et al., 2026; Mchirgui & Sellami, 2025). These studies also highlight that few analyses integrate operational and environmental dimensions within the same framework, even though these two issues are closely intertwined in the regional context.

A second axis focuses on sustainability in port logistics. Yuen et al. (2018) propose a multidimensional perspective, combining CO2 emissions per twenty-foot equivalent unit (TEU) air and water pollution, and energy consumption. Acciaro et al. (2014) and Lam and Notteboom (2014) established the conceptual framework of green port strategies, including the use of clean fuels, shore power electrification, modal shift toward rail or inland waterways, and optimisation of terminal operations. Argyriou and Tsoutsos (2023) extended this line of research to small and medium Mediterranean ports, highlighting the difficulty of translating sustainability ambitions into daily practices in environments marked by congestion and seasonal variability.

A third axis addresses digitalisation and intermodal integration. Heilig et al. (2017) laid the conceptual foundations of Terminal Operating Systems (TOS) and Port Community Systems (PCS) as tools for improving flow efficiency, while Rodrigue (2020) situates these tools within the broader dynamics of global supply chains. The literature converges on a common observation: despite progress in major European ports, digital and intermodal capacities remain unevenly developed across the Mediterranean, with a particularly pronounced gap on the southern shore.

A fourth emerging dimension: ports as energy nodes

These three well established pillars partly overlook a transformation that has accelerated since 2022: the shift of ports into energy transition hubs. Pivetta et al. (2024) study this transformation by showing that decarbonising port industrial zones now relies on three coupled levers: local production of green hydrogen, green ammonia for maritime bunkering, and large-scale electrification. Holder et al. (2024) emphasise that combining these levers redefines ports as energy infrastructures as much as logistics platforms, integrating smart grids, storage, and local renewable energy. At the regional level, the World Bank (2025) report on Moroccan ports as hydrogen hubs and the CETMO and IEMed (2024) work on infrastructure energy digitalisation pillars in Western Mediterranean transport provide early empirical evidence of how these transformations are materialising in concrete ports. This evidence refers to observable, data-based findings drawn from case studies, policy implementation, infrastructure projects, and measured operational changes that demonstrate how sustainability and digital transitions are being put into practice in real port environments.

Research problem and contribution

At the intersection of these literatures, a gap emerges. Research on Mediterranean ports remains largely compartmentalised: sustainability on one side, digitalisation on another, and energy transition emerging as a third silo. Few studies articulate these dimensions within a geopolitical reading of the 5+5 region, even though current energy and digital infrastructure choices are actively reshaping interdependencies between northern and southern shores.

This article addresses this gap by integrating sustainability, digitalisation, and energy as dimensions of a single transformation, and by exploring three related questions:

- how emerging energy sources and AI technologies reconfigure the role of ports in Mediterranean transport;
- how these dynamics materialise in two representative ports, Tanger-Med and Barcelona;
- what opportunities and risks arise for 5+5 regional cooperation and the strategic positioning of countries on both sides of the basin.

The 5+5 region facing new challenges: two ports as indicators of emerging interdependencies

Grounding the analysis in concrete cases highlights these dynamics. Two ports are particularly illustrative: Tanger Med on the southern shore and Barcelona on the northern shore. Both embody the convergence of energy and digital transitions and are already engaged in investment trajectories that will shape the horizon up to 2030. Tanger Med, on the southern shore, illustrates the transformation of a container hub into an energy export node. Barcelona, on the northern shore, combines the arrival of a European hydrogen corridor with the deployment of a leading port based on an artificial intelligence ecosystem (see Figure 1).

Tanger Med: from container hub to energy export node

The leading container port in Africa and the Mediterranean, Tanger Med surpassed 10 million TEUs in 2024. This logistical consolidation is now accompanied by rapid energy transformation.

The port obtained ISO 50001 certification for energy management[1] in December 2024, and since 1 January 2025, all operations are powered by 100% renewable electricity through direct power purchase agreements with national producers (Tanger Med Port Authority, 2025). The deployment of an Onshore Power Supply (OPS) system at terminal TC4 allows docked vessels to connect to green electricity, complemented by a planned 13 MW floating solar plant in the Oued Rmel basin.

This energy positioning anticipates a deeper shift: that of bunkering. The port currently supplies around 1.5 million tonnes of fossil fuels per year to passing vessels (World Bank, 2025). The deployment in January 2024 of the mega con-

[1] ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organisations to integrate energy management into their overall efforts to improve quality and environmental management.

tainer ship Ane Mærsk, the first of its kind capable of operating on methanol, on the Asia-Europe AE7 route serving Tanger Med (Maersk, 2024), marked the beginning of a transition that the International Maritime Organization (IMO) (2023) now makes unavoidable by 2050. Tanger Med is thus preparing to become one of the first Mediterranean bunkering hubs for hydrogen and its derivatives, methanol and ammonia.

This evolution is supported by Morocco's national hydrogen strategy. The 'Offre Maroc' initiative allocates 1 million hectares for green hydrogen development, with major investments involving companies such as Acciona, Total Energies, Engie, and ACWA Power. According to the World Bank (2025), Morocco could meet up to 4% of global green hydrogen demand by 2030, with production costs potentially falling to between 0.6 and 1.3 dollars per kilogram in the most favourable locations. The integrated scenario proposed by the World Bank, known as the Lighthouse Scenario, combines solar production in Tan-Tan, storage in salt caverns in Mohammedia, industrial valorisation in Jorf Lasfar, and maritime bunkering in Tanger Med.

This framework reshapes the port's position within the basin's energy geography. Tanger Med becomes the southern endpoint of a hydrogen and derivatives export corridor toward Europe, complementing future repurposed gas pipelines. However, the resulting geopolitical configuration is not symmetrical: the Kingdom of Morocco simultaneously imports increasing volumes of electricity from Spain, a trend that has grown steadily since 1997, while remaining dependent on technologies, equipment, and expertise largely provided by European operators to develop its own green production capacities.

Barcelona: a storage hub within the European green hydrogen corridor

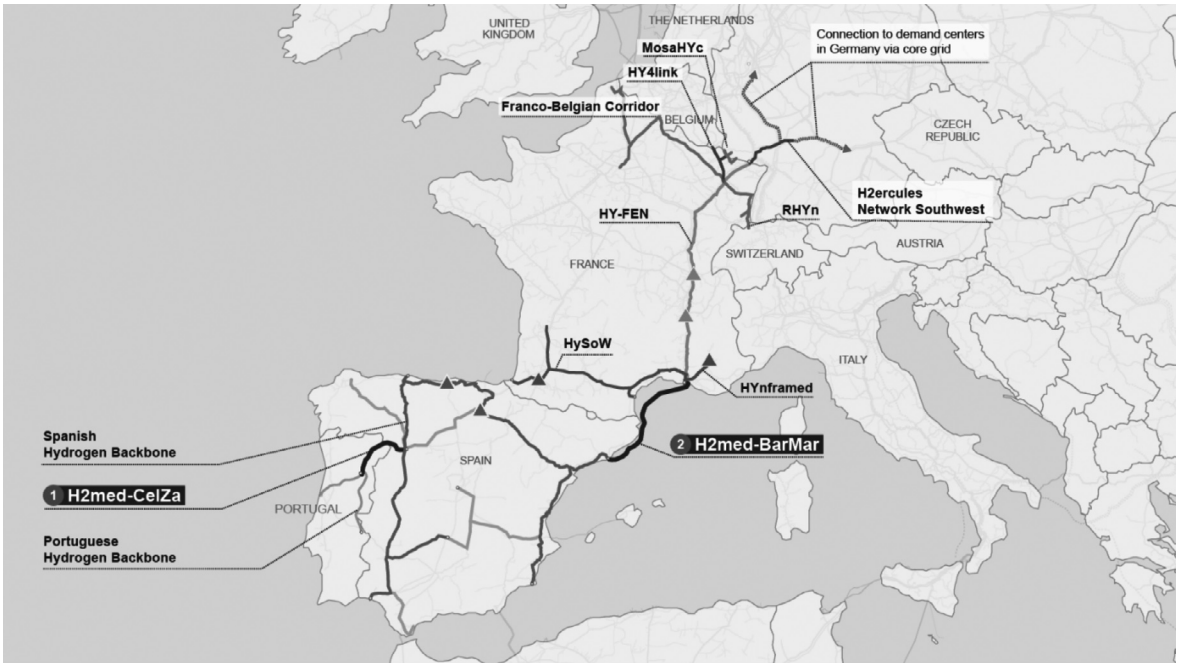
At the other end of the basin, the Port of Barcelona illustrates a different yet convergent trajectory. Its transformation follows an arrival rather than export logic: becoming the Mediterranean terminus of a structuring hydrogen corridor at the European scale, and integrating this new energy function into an already mature industrial and logistics ecosystem.

The energy pivot is driven by the H2med project, formalised in October 2022 by the Spanish, Portuguese, and French governments, and joined in January 2023 by Germany. H2med consists of two cross border infrastructures: CelZa, a 270 kilometre pipeline linking Celorico da Beira in Portugal and Zamora in Spain, and BarMar, a 400 kilometre subsea pipeline connecting Barcelona to Fos-sur-Mer in the Marseille industrial area (H2med, 2025). The system is designed to transport up to 2 million tonnes of renewable hydrogen per year, representing around 10% of the import target set by REPowerEU[2] for 2030 (European Commission, 2022). The project was included in the European Union (EU) list of Projects of Common Interest on 8 April 2024 (European Commission, 2024). Following geophysical surveys conducted in 2024 and in summer 2025, the technical

[2] In response to the hardships and global energy market disruption caused by Russia's invasion of Ukraine, the European Commission is implementing its REPowerEU Plan to phase out Russian fossil fuel imports. Launched in May 2022, REPowerEU is helping the EU to save energy, diversify energy supplies, and produce clean energy. https://commission.europa.eu/topics/energy/repowereu_en

feasibility of the BarMar route was confirmed in November 2025 by the operators Enagás, NaTran, REN, Teréga, and OGE, with commercial commissioning now planned for 2032 (H2med, 2025). The dedicated company, BarMar, was created in July 2025 to lead the interconnection project.

Figure 1. Illustration of the H2med project, aimed at supplying north-western Europe with hydrogen from the Iberian Peninsula by 2032



Source: H2med (2025).

For Barcelona, this positioning transforms the port into a strategic entry point for a flow of renewable hydrogen produced in the Iberian Peninsula, primarily from solar and wind energy. The geopolitical significance is considerable: according to corridor operators, the Iberian Peninsula could export more than 1.6 million tonnes of hydrogen per year as early as 2030 and reach full capacity by 2032 (H2med, 2025), while Germany could import up to 1.6 million tonnes per year by 2040. The Catalan port thus occupies, on the northern shore, a position that is symmetrical to that of Tanger Med on the southern shore, but inverted: no longer an export point for green energy to Europe, but an entry point for a structuring flow essential to the decarbonisation of the continent's industry.

This architecture confirms that the Mediterranean energy transition is unfolding through a limited number of large-scale infrastructures whose routing, timing, and governance decisions will shape the organisation of flows between shores for the next two to three decades. While other complementary or smaller-scale energy projects also exist, the focus here is on the major cross-border hydrogen transport and export infrastructures because of their disproportionate structuring effect on regional flows, investment priorities, and long-term geopolitical interdependencies.

Table 1. Tanger Med and Barcelona: comparative trajectories in the energy and digital transition

Dimension	Tanger-Med	Barcelona
Geographic position	Southern shore, Strait of Gibraltar	Northern shore, Western Mediterranean
Container traffic 2024	More than 10 million TEUs	3.89 million TEUs (+18.5% vs 2023)
Emerging energy role	Hydrogen export hub and alternative fuel bunkering node	Hydrogen imports terminus (BarMar / H2med)
Port energy status	100% renewable electricity since 1 January 2025	First operational shore power system for container ships since July 2024
National strategic framework	Morocco Offer 2024 (1 million hectares, 319 billion dirhams committed)	H2med, EU PCI 2024, commissioning planned for 2032
Key stakeholders	Acciona, TotalEnergies, Engie, ACWA Power	Enagás, NaTran, REN, Teréga, OGE
Position in value chain	Producer and exporter of green molecules	Import hub with downstream industrial valorisation
Type of dependency generated	Incoming technological dependence (equipment, engineering, intellectual property)	Incoming energy dependence (molecules)

Source: Compiled by the author based on Tanger Med Port Authority (2025), Port de Barcelona (2025), World Bank (2025), Kingdom of Morocco (2024), and H2med (2025).

Cross-cutting analysis: energy, technological, and data asymmetries

Comparing the two cases (see Table 1) reveals three layers of interdependence that are being reshaped simultaneously in the 5+5 region. The first layer, energy related, shows the emergence of a structuring flow of green molecules from South to North, coupled with an existing flow of electricity from North to South. The second layer, technological and industrial, remains highly unevenly distributed: high capacity electrolysers, hydrogen pipeline engineering, and industrial storage and bunkering capabilities are largely concentrated on the northern shore or controlled by European operators. This places southern shore countries in a position of technological dependence at the very moment they are becoming producers and exporters. The third layer, financial and operational, is driven by a small number of integrated actors orchestrating both ends of the corridor: European energy groups involved in the Morocco Offer (Acciona,

TotalEnergies, Engie, ACWA Power) and gas transport operators behind H2med (Enagás, NaTran, REN, Teréga, OGE). Through their dual functions as both logistical and energy interfaces, Mediterranean ports thus become key observation points for these structural shifts, and places where current investment decisions will shape power relations between shores on either side of the Mediterranean for the next two to three decades.

Risks, opportunities, and strategic positioning: toward renewed North-South port cooperation

Three complementary perspectives help frame the situation for renewed North-South port cooperation: the structural risks accompanying the current trajectory, the levers for a more balanced form of cooperation, and the implications for the strategic positioning of each shore.

Risks: the possible reproduction of structural asymmetries

Three risks emerge from the previous analysis. The first is a risk of extractive specialisation: the southern shore currently appears primarily as a producer of green molecules, while downstream industrial value, whether in chemicals, refining, green steel, or heavy mobility, remains overwhelmingly located on the northern shore and in Central Europe. The current trajectory of the Morocco Offer, which mainly mobilises European and international industrial actors as operators (Kingdom of Morocco, 2024), tends to reproduce this pattern. The second risk concerns technological dependence: the manufacturing of high capacity electrolysers, hydrogen pipeline engineering, storage and bunkering systems, as well as related certification and metrology capabilities, are concentrated in a limited number of European, Asian, and North American actors (Pivetta et al., 2024; Holder et al., 2024). The third risk is more institutional, relating to governance asymmetry. The standards governing renewable fuels of non-biological origin (RFNBO) and eligibility mechanisms for European markets are defined by the EU under the REPowerEU framework and the Fit for 55 package (European Commission, 2022), with which southern shore producers must comply without fully participating in their design.

Opportunities: levers for a more balanced North-South cooperation

However, these risks are not inevitable, and several rebalancing levers can be identified. The first is industrial co-localisation: transforming part of the green hydrogen produced in the South into higher value intermediate products such as green fertilisers, green steel, bunkering ammonia, or e-fuels for aviation and shipping. The integrated scenario proposed by the World Bank (2025) for Moroccan ports illustrates this logic by coupling production, storage, and industrial valorisation. The second lever lies in the co-development of industrial and technical capacities: training programmes, joint ventures, shared intellectual property on electrolysers and bunkering systems, as well as the local establishment of assembly and maintenance units. The third lever involves existing financial mechanisms, notably the European Clean Hydrogen Partnership, the European Investment Bank (EIB), bilateral funds between France, Spain and Morocco, as well as World Bank green financing facilities. A

fourth, more subtle but long-term decisive lever concerns regulatory and normative convergence: mutual recognition of renewable origin certificates and harmonisation of measurement and traceability protocols would provide southern producers with fairer access to northern markets (CETMO/IEMed, 2024).

Strategic positioning of both shores of the Mediterranean

For the southern shore, the ongoing energy transition offers a historic opportunity for technological leapfrogging, provided that current investment choices incorporate, from the outset, an industrial upgrading strategy. Otherwise, the likely scenario is one of primary specialisation extended to green molecules, which would reproduce in a renewed form the extractive logic of previous cycles. For the northern shore, the situation is different: the challenge is to secure a nearby decarbonised energy supply in a context where the war in Ukraine has revealed the fragility of long-distance dependencies, and where the maritime net zero timeline set by the IMO (2023) requires long term industrial visibility. This requires investing in the climate and cyber resilience of energy and digital corridors, and committing to more structurally embedded partnerships with southern countries than traditional trade schemes allow.

For the ports themselves, such as Tanger Med or Barcelona, the change in status is qualitative: they become full-fledged points of strategic sovereignty, which requires simultaneously considering their energy infrastructure, digital architecture, shared governance, and shock absorption capacity. The challenge for the GTMO 5+5 and associated institutions is therefore not only technical or regulatory. It is to build a cooperation architecture that transforms interdependencies into co-dependencies, meaning relationships in which each shore bears an equivalent level of risk and captures a balanced share of the value created.

Conclusions and recommendations

Conclusions

The analysis conducted in this paper leads to four main conclusions. First, Western Mediterranean ports have become the physical nodes of at least four overlapping transitions: operational sustainability, digitalisation, energy transition, and geopolitical reconfiguration. Scientific literature has long treated these dimensions separately, whereas they are now increasingly intertwined in concrete investment choices observed on the ground. Second, the cases of Tanger Med and Barcelona illustrate two complementary trajectories, one export-oriented and the other import-oriented, which together structure the emergence of a Euro-Mediterranean energy corridor articulated with an existing logistics corridor.

Third, these trajectories nevertheless unfold according to a logic that remains highly asymmetrical in terms of the capture of industrial, technological, and normative value added, which is primarily concentrated on the northern shore. Fourth, infrastructure, financing, and governance decisions taken in the coming years will have a structuring effect for two to three decades, making the current period particularly decisive. The central risk for regional cooperation is therefore not the absence of investment or partnerships, but their development in an asymmetric manner that could transform a shared transition opportunity into a new form of extractive dependence.

Recommendations

Three operational recommendations emerge from this analysis:

A. Explicitly place regulatory and normative convergence as a priority of the Group of Western Mediterranean Transport Ministers, by working on mutual recognition of renewable origin certificates, harmonisation of hydrogen metrology, and port cybersecurity standards, within the framework of dialogue with the EU and the IMO.

B. Systematically link European and international financing mobilised in the Mediterranean energy transition, whether from the Clean Hydrogen Partnership, the EIB facilities, or the World Bank, to contractual clauses on industrial co-development and capacity transfer toward southern shore countries, in order to avoid long-term primary specialisation.

C. Under the auspices of CETMO and the MedThink 5+5 network, create a joint North South monitoring and evaluation mechanism that tracks the actual evolution of logistics chains, deployed technologies, and structural dependencies in Mediterranean corridors, in order to provide decision-makers and ports with a shared knowledge base and best practices to adjust maritime and port strategies in support of operational excellence, data driven digital innovation, and the energy transition.

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The Value of Investing in Climate Adaptation in the Transport Sector in the Western Mediterranean and its Financing

Juan Alario
Former Associate Director, European Investment Bank

Joan Ignasi Alario Piedra
GNE Finance

Introduction

For low- and middle-income countries (LMICs), adaptation funding needs are $310 billion to $365 billion per year by the year 2035, according to the 2025 United Nations Environment Programme (UNEP) Adaptation Gap Report. These figures are at least 12 times current international public adaptation finance flows. Just for the European Union (EU), for example, the investment needs have been recently estimated at €69 billion per year up to 2050 (European Commission, 2026).

National infrastructures, including transport, energy, and water systems, are originally designed to withstand climate hazards, such as flooding, strong winds, storms, and heatwaves. However, the climatic conditions projected at the time of their design differ substantially from those expected today. As a result, climate change requires a systematic reassessment of these infrastructures in light of expected climate risks, and, where required, their adaptation to future conditions. This represents a large-scale and long-term undertaking that is already underway in many countries and will take years to complete.

For the EU as a whole, the current annual adaptation funding for transport is estimated at €3.35 -2.85 billion (EEA, 2025). According to the European Environmental Agency (EEA) (ibid.), the transport sector will require €7-8 billion per year for transport resilience by mid-century, and under a high warming scenario, this could rise to €12–25 billion per year by 2100. These figures, which are highly speculative,[1] are comparable to or exceeding current annual infrastructure maintenance budgets in many countries. We did not find information on the current and future adaptation investment needs for the transport sector in the five African countries of the 5+5 initiative. Similarly, only seven out of the 27 EU member states had national studies quantifying transport climate adaptation finance needs, according to a recent study (ibid.). Out of the five European countries of the 5+5 initiative, only France and Italy have carried out this quantification. Therefore, the identification of the amount of investment required is at an early stage, but as per the above study from the EEA, the investment needs are expected to be very large.

Economic, social and environmental benefits of adaptation investments should outpace costs by a significant margin.[2] However, the EEA (ibid.) concludes that the economic benefits do not cover adaptation costs in the transport sector in the EU. The primary reason for this paradox is likely related to data and scope limitations. The benefits are drawn from existing models that capture only a portion of climate damages. When more sophisticated models are used, economic benefits tend to outpace costs, hence the importance of using such models (see sections 3 and 4).

Efforts to accelerate infrastructure adaptation face not only significant financial constraints, but also technical and logistical challenges, including the mobilisation of labour and materials at scale. In addition, careful planning will be required to minimise societal and economic disruptions (such as traffic disruptions) associated with major rehabilitation works. These dynamics are especially pressing in transport infrastructure, which have long life-spans (ibid.). For example, bridges are designed

[1] Only a handful of EU countries have quantified transport adaptation finance needs.

[2] According to the World Resources Institute (WRI), every $1 spent on adaptation can yield up to $10 in economic, social and environmental benefits over 10 years.

to last between 50 and 100 years, rail tracks 50 years, and road surfaces might be renewed every 10-20 years. Depending on the climate adaptation strategy adopted, the annual investments in adaptation can vary significantly.

For instance, if a public transport entity or company decides to invest in climate adaptation only when an asset is due for renewal, or when a major rehabilitation has to be carried out or after damages occur, the upfront investment may be small. However, the overall process of adapting infrastructure to future climate hazards would take a very long time. This delay would leave infrastructure exposed to significant climate risks, resulting in substantial costs over time, both for repairs and in terms of broader socioeconomic impacts. As such, it is necessary to invest in renovating infrastructure exposed to high climate risks as soon as possible in order to enable their timely (and economically efficient) adaptation, even if they are not due for replacement or renovation.

This article addresses the following two questions: 1) What are the obstacles when mobilising the amount of climate adaptation finance needed for the transport sector? 2) How should the benefits of a climate adaptation transport project be assessed? The focus is on the five Northwest African countries of the 5+5 initiative: Morocco, Mauritania, Libya, Tunisia and Algeria.

Mobilising climate adaptation financing: an overview

In most LMICs, mobilising public capital to finance climate adaptation is not easy, as capacity to expend for additional investment is limited. As a result, a substantial part of public investment comes from international finance sources. Multilateral Development Banks (MDBs) and bilateral public institutions play a critical role in providing competitive and long-term financing to these countries, often including grants and technical assistance. Mobilising private capital from international or national capital markets or commercial banks for climate adaptation is generally costly and limited. Considering the substantial climate adaptation financing required, it will be increasingly necessary to mobilise private capital at scale for climate adaptation, as is already happening for climate mitigation. MDBs can also play a critical catalytic role in facilitating the mobilisation of private capital by offering political risk coverage, such as through the World Bank's Multilateral Investment Guarantee Agency (MIGA) or the International Finance Corporation's (IFC) A/B loan programme.

MDBs accounts for 56.5% of the total financing for climate adaptation provided or mobilised by high-income countries (HICs) to LMICs in 2022 (UNFCCC, 2024). Bilateral financing accounted for 32.7%, and the private financing mobilised was just 10.8%. Details of the financing provided by each country are not available.

Climate adaptation financing from MDBs to LMICs has increased substantially in recent years; from $13.9 bn in 2019 to $26.3 bn in 2024, based on a comparable methodology to define climate adaptation investments (EIB, 2024). This reflects the commitment by MDBs, at the UN Secretary General's Climate Action Summit in New York in September 2019, to increase their climate action financing substantially by 2025, including doubling adaptation finance to $18 bn in the same year, which

they have surpassed. The Glasgow Climate Pact in 2021 also foresaw a substantial step up of adaptation financing.

Out of this total, the percentage of grants provided by MDBs varies substantially. It is the largest share of the total financing provided by MDBs for low-income countries, while it is a minor share for middle income countries, where they mostly provide debt financing. In the Middle East and North Africa (MENA) region, most adaptation financing provided by MDBs has gone to water and wastewater systems and energy, transport and the built environment (i.e., buildings).

Typically, 90% of MDBs' adaptation financing has gone to public sector borrowers (i.e., governments, public agencies or state-owned entities). Most of the financing corresponds to investment loans to finance projects or programmes (EIB, 2024). One example is an EIB framework loan, signed in February 2026, granted to the Société Nationale des Autoroutes du Maroc to enhance the resilience of Morocco's primary expressway network to climate change and other hazards.

There are several innovative climate adaptation financing instruments that are being proposed or tested, such as adaptation benefits mechanisms, and climate resilience swaps[3] (IISD, 2025).

Under the adaptation benefits mechanism, project developers sign Adaptation Benefits Supply Agreements (ABSAs), or offtake agreements, with organisations that agree to pay the project developer for quantified adaptation benefits. This is an example of financial mechanism that could be used to mobilise private capital to finance climate adaptation projects. These types of agreements could be used as a basis to raise debt financing for climate adaptation projects, based on lending against the benefits generated by the project. A key issue in this approach is to properly quantify adaptation benefits with the reliable tools, which is developed in section 3 and 4.

In addition to providing financing, international finance institutions (IFIs) and other international institutions provide technical assistance (TA) for climate adaptation. Examples include the World Bank - Africa Climate Resilient Investment Facility (AFRI-RES), or the EIB - ADAPT (Climate Adaptation Investment Advisory Platform). As climate adaptation is at an early stage of development in many LMICs, including for the transport sector,[4] TA is fundamental, both for developing transport climate adaptation plans and to evaluate and structure the financing of climate adaptation investments in these countries. For instance, Morocco has received support from the EIB to develop a climate adaptation plan for the Moroccan rail network.[5]

[3] This arrangement allows debtor countries to redirect resources from debt servicing toward biodiversity protection or climate resilience efforts.

[4] See also the new regional initiative of the International Center for Numerical Methods in Engineering (CIMNE), the International Union of Railways (UIC) and CETMO, in collaboration with the Union for the Mediterranean (UfM), to strengthen climate resilience in Mediterranean transport: https://cimne.com/strengthening-climate-resilience-in-mediterranean-transport-cimne-and-cetmo-begin-new-regional-initiative-with-union-for-the-mediterranean-ufm/

[5] https://www.eib.org/en/press/all/2024-367-la-bei-signe-un-partenariat-d-assistance-technique-avec-l-oncf-pour-soutenir-l-adaptation-de-son-activite-ferroviaire-au-changement-climatique

The economic and financial evaluation of climate adaptation projects

The economic evaluation of climate adaptation projects has evolved significantly over recent decades, moving beyond simple impact assessments toward more complex frameworks with greater data and methodological requirements (Fankhauser & Soare, 2013). Current approaches are increasingly grounded in the Hazard, Exposure and Vulnerability (HEV) framework developed by the Intergovernmental Panel on Climate Change (IPCC, 2012, 2014), where risk is conceptualised as the product of hazard, exposure, and vulnerability. While hazard refers to the impact on the environment the climate risk poses, exposure quantifies the people, assets, or ecosystems affected by those hazards. Vulnerability estimates the level of damage the hazard would cause on the exposure, for example, estimating the level of damage a windstorm would cause on a rail line or estimating the impact of chronic precipitation decrease on desertification, particularly important for transportation networks, as it can severely reduce infrastructure lifespan through increased erosion rates.

Together, these components feed into an impact function used to estimate the cost of inaction, defined as the expected damages in the absence of adaptation measures. This serves as a benchmark against which adaptation options are evaluated. The benefits of adaptation in the transport sector[6] correspond to avoided costs, including direct damages such as repairs, accidents, and revenue losses, wider economic impacts such as delays, business disruption, and reduced transport demand, and indirect effects including changes in employment, investment, and transport efficiency (Steen et al., 2022). The avoided costs are the financial benefits for the transport company of a climate adaptation project.

In practice, MDBs structure the economic evaluation of adaptation projects around three stages to obtain a probabilistic distribution of their economic profitability:

1. Risk quantification layer: Assesses the economic damages, increasingly HEV-based, in the context of the transportation sector, often combined with a model of the transportation network.
2. Economic appraisal layer: Evaluates the economic profitability of adaptation investment options by comparing the cost of an option with the reduction of the economic damages generated by the investment.
3. Uncertainty layer: Addresses the probabilistic nature of climate risk impacts and adaptation benefits.[7] This stage is critical, as the benefits of adaptation depend on uncertain future climate risks and their associated impacts.

Recently, a methodology named the Economics of Climate Adaptation (ECA) has been developed precisely to allow decision-makers to assess climate risks and adaptation solutions in a systematic way rather than on an ad-hoc basis (Bresch, 2016). Sometimes, much more

[6] These analytical stages are often combined with transport network modelling tools, including criticality analysis and scenario-based disruption modelling. While such integration enhances analytical depth, it also increases complexity and the risk of compounding errors, requiring careful implementation (Farahmand et al. 2024).

[7] This is done through tools such as Monte Carlo and Quasi Monte Carlo simulations, scenario analysis, stress testing, and Robust Decision Making, which is a method for identifying hazard response strategies.

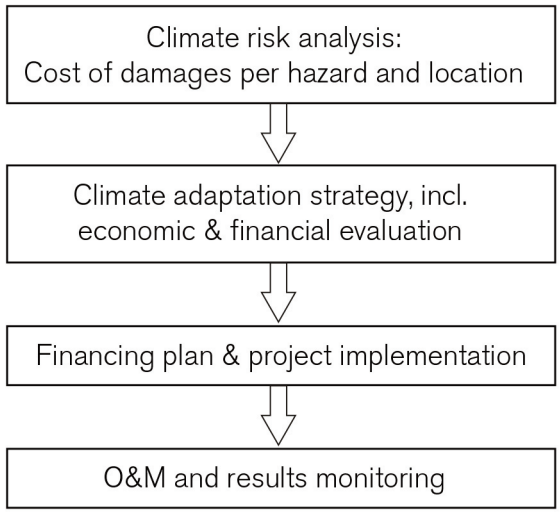
accessible indicator-based or index-based vulnerability frameworks are employed, for example providing a flood risk score to a particular geographical area (high, medium, low risk). These frameworks have the advantage of being simple to implement, but can be low in precision, underestimating or overestimating certain risks or costs (EEA 2025, p. 30). This is especially important in the transportation sector, where meter level precision is often essential for accurately mapping risks and quantifying impacts. For example, simpler models have frequently underestimated the benefits of climate adaptation measures because they fail to identify the specific infrastructure segments exposed to flooding and to multiple overlapping hazards within the same location.

Adapting the economic and financial evaluation to the transport sector

We argue that a good way to rank climate adaptation investments in the transport sector is to do so on the basis of their economic profitability, based on the socio-economic benefits generated by the project in question. Obviously, other factors may also be taken into account in the decision, such as technical or organisational.

As per Figure 1, the integration of climate adaptation into infrastructure planning typically follows a sequential process. First, the expected costs of damages from climate-induced events, such as flooding or heatwaves, are assessed across different locations of the transport network. Second, based on this analysis, a strategy to reduce these damages is defined by comparing the costs and expected benefits of alternative adaptation measures. Then, the best option is selected. This strategy should be aligned with national policies and resilience frameworks, and any inconsistencies with relevant adaptation strategies should be addressed. To remain responsive to evolving climate risks, priority should be given to flexible investments that can incorporate new information over time.

Figure 1. Integration of climate adaptation in an infrastructure investment programme



Source: Compiled by the authors

This approach ensures that selected climate adaptation projects generate sufficient socioeconomic benefits to justify their costs, a criterion typically required by MDBs.

In addition, a financial evaluation should be conducted from the perspective of the project promoter to assess whether financial benefits are sufficient to cover investment costs. Where this is not the case, external support, such as grants, might be necessary. The financial benefits in the case of a private company or the economic benefits in the case of a public entity, could be the basis to mobilise private capital, using for instance innovative financial instruments, as mentioned in section 2.

In the transport sector, the analytical framework described in Figure 1 is ideally operationalised through a set of sector-specific modelling tools and data inputs. As per Figure 2 below, these are often combined to assess how climate-induced disruptions propagate through transport systems. A key component is transport network analysis, including criticality analysis, which identifies the most important links in the network and models the system wide impacts of disruptive events (Mylonas et al., 2023). This allows the assessment of how localised hazards translate into broader network level disruptions.

Ideally, once the climate adaptation strategy has been set up, a detailed feasibility study should be carried out for each project and a plan to finance the investments should be prepared.

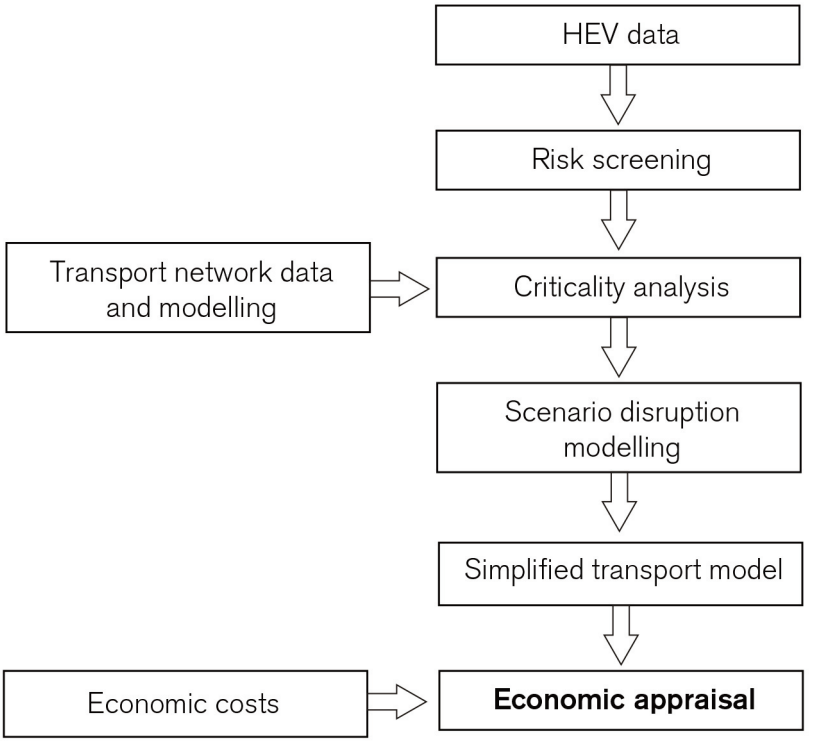
Then, monitoring should be implemented, as required by IFIs. This should extend beyond tracking outputs, such as kilometres of infrastructure upgraded, to include benefits and outcomes, such as levels of protection against specific hazard intensities or reductions in service disruptions. The monitoring of the climate adaptation benefits is very useful for future projects.

The robustness of such analyses depends not only on methodological design but also on the quality and availability of underlying data. Climate hazard data, often derived from Regional Climate Models (RCMs), is uneven in spatial coverage and resolution. In many regions, high resolution and bias corrected data are limited or unavailable. Bias correction - when results of studies are corrected with historical data and other study results - is extremely important when it comes to RCMs, as it can have a significant impact on the reliability of the data (Wamahiu et al., 2023).

Similar constraints apply to socioeconomic data. Estimating exposure and vulnerability requires detailed demographic and asset information, which is readily available in some contexts, such as the EU, but largely absent or incomplete in others. In Morocco, Tunisia, Algeria, Mauritania and Libya the situation is mixed, with data sometimes highly detailed and accessible, other times with low detail, not very openly accessible or sometimes not collected, or extremely outdated when it comes to conflict zones. In data-scarce contexts, proxy indicators derived from satellite observations, such as night-time light intensity, are often used to approximate population distribution and asset value (Eberenz et al., 2020).

Data limitations also extend to transport system representation itself. The density and quality of traffic sensors, as well as the completeness of network mapping and information on infrastructure condition, vary significantly across regions. As a result, the accuracy of transport modelling differs substantially depending on data availability and quality. Thus, analysis has to be performed with caution, especially when highly diverse regions are being studied.

Figure 2. Structure of the analysis of a climate adaptation for a transportation project



Source: Compiled by the authors

A final consideration is that the level of methodological development varies significantly across transport subsectors. Road and rail infrastructure are generally far more extensively studied and benefit from more standardised approaches than aviation or maritime systems. In addition, robust analysis should not be limited to individual transport networks in isolation, but should also account for interactions across modes and with other sectors, as these interdependencies can significantly shape system level outcomes (Steen et al., 2022).

At this initial stage of the development of climate adaptation investments, it seems necessary to develop pilots of climate adaptation projects to collect relevant data, predictability and increase confidence for the company and investors. For example, the EU Climate ADAPT's RESIST, which consisted on two pilot projects, where new techniques to minimise both natural and man-made extreme events on seamless transport operations were tested and monitored.

Conclusions

Climate adaptation has been a growing priority in national climate plans, including in the 5+5 countries, and in the financing priorities of MDBs and bilateral financing institutions. The investment required to adapt to climate change is large. Mobilising this capital is challenging. For this reason, IFIs are playing a substantial role to finance climate adaptation investment. MDBs can provide long-term competitive financing well adapted to these investments. How-

ever, as the investment required is large, it will be increasingly necessary to mobilise private capital for climate adaptation. Some innovative financing methods can facilitate this mobilisation.

Climate adaptation investments in transport infrastructures generate substantial socioeconomic benefits. These benefits should outpace the adaptation costs, but detailed analysis using sophisticated models is needed to make such assessments.

Climate adaptation must be systematically embedded within the project cycle of transport infrastructure planning, with economic and financial analysis forming a central component of this process, as suggested by MDBs. This is necessary to ensure that the expected socio-benefits of adaptation investments exceed their costs. It is also necessary to develop pilots of climate adaptation projects to collect relevant data, establish predictability and inspire confidence for investors.

In this contribution, we have outlined a set of increasingly sophisticated tools to estimate the benefits of climate adaptation, which allow for a more precise quantification of avoided damages and system-wide impacts. While simpler tools and indicators have long been used in practice, they risk producing partial or less precise assessments, particularly when dealing with complex and interdependent transport systems under climate uncertainty.

Recommendations

- **5+5 countries should accelerate the preparation of national adaptation plans for the transport sector,** if they have not done so yet.
- **These plans should apply best practice standards**, in line with recent developments, in order to identify and evaluate with accuracy climate adaptation investments in their transport infrastructure. This includes performing economic and financial evaluations, as outlined in this paper, in order to select and prioritise investments that maximise socioeconomic benefits.
- **Actions to accelerate the required investment are necessary,** as there is often a significant gap between plans and investment implementation.
- **Develop climate adaptation pilots** using sophisticated methods to assess the economic and financial benefits of climate investments and in some cases using innovative financial methods able to mobilise private capital. This will allow drawing lessons for future projects.
- **5+5 countries should take actions to maximise the use of TA funds and adaptation financing** provided by MDBs and other international financial institutions, as these institutions can provide long-term competitive finance and political coverage, which is what is required to finance these investments.

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Financing Resilient Transport Infrastructure in the Western Mediterranean: Mobilising European, Multilateral and Private Capital

Andrea Tinagli
Senior Associate Fellow, IEMed

Introduction

Mobilising the financial resources required to modernise transport systems and strengthen their resilience to climate change is one of the most complex challenges facing the Western Mediterranean region. This article draws on analysis of development finance operations and policy dialogue across the Mediterranean over the past several decades; many of the observations reflect operational lessons emerging from infrastructure financing practices within European and Multilateral Development Banks (MDBs). The focus is specifically on the five Southern Mediterranean countries participating in the 5+5 Dialogue (Morocco, Algeria, Tunisia, Libya and Mauritania, hereforth referred to as 'the 5 South Med countries'), unless otherwise explicitly stated.

A useful starting point for analysing the infrastructure financing ecosystem in the 5 South Med countries lies in Official Development Assistance (ODA), i.e., financial flows provided by official agencies with the primary objective of promoting economic development and welfare in eligible countries. To qualify as ODA, these flows must be provided by official agencies, administered with the promotion of economic development and welfare as the main objective, and concessional in character (OECD DAC, n.d.). Across the Middle East and North Africa (MENA) region, ODA flows have remained significant but variable over time, depending on geopolitical and humanitarian conditions. Total gross ODA disbursements to North Africa averaged approximately $10 billion annually between 2013 and 2024, with economic infrastructure - including transport, energy and water systems - accounting for a notable but variable share across periods (OECD DAC, 2024).

However, the scale of infrastructure investments far exceeds available concessional financing, highlighting the necessity to mobilise additional sources of capital. Infrastructure investment needs for the MENA region are estimated at 5.6% of GDP per year in capital expenditure alone (Rozenberg & Fay, 2019, p. 7), suggesting annual capital investment requirements of approximately $27 billion for the five Southern Mediterranean countries covered in this analysis (World Bank, 2024).

This gap between available concessional resources and infrastructure investment needs has therefore led development institutions to increasingly rely on blended finance mechanisms, designed to combine concessional public resources with MDBs' lending and private capital. Blended finance structures combine several financial components within a single investment framework. Grants may support project preparation or reduce capital costs, while concessional loans may finance public investment components. MDBs' financing provides long-term debt, while their guarantees or risk-sharing instruments help attract private investors. By distributing risks across several financial actors, blended finance mechanisms help address one of the most persistent barriers to infrastructure investment in Low-and Middle-Income Countries (LMICs): the difference between the level of risk perceived by private investors and the long-term development benefits associated with infrastructure projects (OECD, 2018).

Financing ecosystem of transport infrastructure in the Western Mediterranean (recent developments)

Large-scale transport infrastructure projects cannot be financed by a single actor and instead rely on a complex and evolving

ecosystem of institutions. Rather than providing an exhaustive quantification of total financing flows, which remain only partially captured across public and private sources, this section outlines the main categories of actors currently shaping transport infrastructure investment in the 5 South Med countries.

At the forefront, the European Investment Bank (EIB) has played a central role in financing transport infrastructure in the southern shore of the Mediterranean. Historical data from the Facility for Euro-Mediterranean Investment and Partnership (FEMIP) indicates that, between the early 2000s and the mid-2010s, EIB lending to the transport sector amounted to approximately €2.5 billion, representing around 17% of its total financing in Mediterranean partner countries. More recently, under EIB Global, it has continued to support transport infrastructure in the region through operations such as the Zouerate-Nouadhibou railway in Mauritania (AfDB & EIB, 2025) and broader infrastructure programmes in Morocco (EIB, 2025). Recent operations also include the €210 million Sfax-Kasserine road corridor in Tunisia, safety audits for Algeria's highway network, and ongoing technical dialogue to prepare for future infrastructure recovery in Libya.

Complementing this, the European Bank for Reconstruction and Development (EBRD) has significantly increased its investments in the 5 South Med countries in recent years, among others supporting sustainable rail through green bonds for Morocco's Office National des Chemins de Fer (ONCF) (EBRD, 2025). Simultaneously, the World Bank Group (WBG) plays a significant role in supporting urban and maritime connectivity projects, recently approving $350 million for the Casablanca-Settat regional rail (Service Intramétropolitain Rapproché - SIR). Its private sector arm, the International Finance Corporation (IFC), selected financing operations related to the Tanger Med port complex (World Bank, 2025).

In addition to MDBs, bilateral development finance entities are relevant players. Institutions such as the Agence Française de Développement (AfD) and Kreditanstalt für Wiederaufbau (KfW) are among the most active providers of long-term financing and technical assistance in the region, frequently co-financing projects alongside MDBs. Their operations typically combine sovereign lending, grants and technical cooperation, contributing to project preparation and implementation capacity, an example being sustainable urban transport initiatives in cities such as Casablanca (IEMED & CETMO, 2021). Domestic public financial entities from the 5 South Med countries, including national development banks and sectoral financing agencies, also play a role, although their capacity and mandate vary significantly across countries. In some cases, they act as intermediaries for international financing or contribute to co-financing of strategic infrastructure projects, while in others their role remains limited due to balance sheet constraints or institutional capacity.

Beyond public lending, the private sector plays an increasingly important role. Major international and regional commercial banks, such as Attijariwafa Bank, Banco Santander and BNP Paribas, are active in providing syndicated loans.[1] According to the EBRD, its investment activity in the Southern Mediterranean region reached approximately €2.8 billion in 2025, including a substantial contribution from private sector co-financing estimated at around

[1] Commercial Banks (Syndicated Loans): Refers to Project Finance structures where groups of banks (e.g., Attijariwafa Bank, Société Générale) share the risk of large port or highway concessions.

€747 million (i.e., 26% of total financing). Furthermore, infrastructure investment funds, such as Africa50 and Meridiam, are increasingly active in transport infrastructure concessions. Examples include container terminal developments in the port of Nouakchott, in Mauritania. Risk mitigation instruments provided by the Multilateral Investment Guarantee Agency (MIGA), part of the WBG, also play an important role in supporting infrastructure investments.

Financial architecture for external investment: European instruments and other international approaches

The central framework for European Union (EU) external action during the current programming period is the Neighbourhood, Development and International Cooperation Instrument (NDICI – Global Europe). With a total budget of approximately €79 billion for the period 2021/2027, NDICI – Global Europe represents the largest financial instrument ever created by the EU for external cooperation and investment. At the centre of this architecture lies the European Fund for Sustainable Development Plus (EFSD+), which serves as the EU's main risk-sharing mechanism for external investment operations (European Commission, 2021a).

The EFSD+ guarantee system is designed to improve the risk profile of investment projects in the EU's partner countries, thereby enabling MDBs and financial institutions to undertake operations that might otherwise be considered too risky. The mechanism is allowing guarantees to cover up to €40 billion worldwide. By absorbing part of the financial risk associated with these investments, the guarantee enables financial institutions to mobilise significantly larger volumes of capital than would be possible using EU grants alone.

Global Gateway is not a separate financing facility but a strategic policy framework through which EU external investments, primarily financed via NDICI – Global Europe and EFSD+, are prioritised and coordinated. Launched in 2021, Global Gateway represents the EU's strategic framework for infrastructure connectivity with the EU´s partner regions, including Africa, the Mediterranean and Asia. The initiative originally aimed to mobilise up to €300 billion in investment between 2021 and 2027, focusing on sectors such as transport, energy, digital infrastructure and climate resilience (European Commission, 2021b). Following progress reported during the Global Gateway Forum in October 2025, the European Commission announced an increased mobilisation objective of €400 billion by 2027. To support implementation, the European Commission has also established the Global Gateway Investment Hub, intended to facilitate coordination between European development finance institutions, EU instruments and private investors, while providing a structured entry point for project development and investment opportunities.

In the Southern Mediterranean, Global Gateway is supporting a broad range of sectors. In transport, investments have focused on modernising rail and port infrastructure in Morocco (i.e., ONCF and Tanger Med) and Tunisia (i.e., SNCFT-Société Nationale des Chemins de Fer Tunisiens and strategic corridor Sfax-Kasserine streamlining trade routes between the Mediterranean and sub-Saharan Africa). In energy, the flagship ELMED interconnector project between Tunisia and Italy aims to strengthen cross-border electricity integration and renewable energy trade. In digital infrastructure, the Medusa submarine

cable has enhanced connectivity between European and North African countries. Water security and climate resilience have also been addressed through large-scale desalination and resource management projects.

Alongside European and multilateral approaches, other international financing models have also contributed to infrastructure development in the broader Mediterranean region, including those associated with Chinese investments. Chinese-supported infrastructure financing has often been characterised by highly integrated project structures, in which financing, provided by Chinese policy banks, is combined with engineering, procurement and construction (EPC) contracts implemented by Chinese firms, and usually followed by operational involvement of state-owned Chinese enterprises such as COSCO Shipping. A prime example in the Mediterranean is Greece's Port of Piraeus, where COSCO Shipping's acquisition of a controlling stake enabled a massive expansion programme. This investment strategy combined equity with operational oversight, driving growth in both capacity and container traffic. Despite being implemented under EU regulations during Greece's economic rescue, the project illustrates a clear intent to involve Chinese players at every possible level.

A fundamental distinction between these approaches lies in their institutional and operational frameworks. European and MDB-supported projects typically prioritise transparent procurement-based competition, a clear separation between financing and implementation, and strict adherence to environmental and social safeguards (i.e., Paris Agreement and ESG criteria). In contrast, the Chinese approach often relies on integrated arrangements characterised by closer coordination between financing entities, construction firms, and operators with less emphasis on sustainability. While these structural differences influence implementation timelines, risk allocation, and governance, final outcomes remain contingent on project design, national context, and local institutional capacity.
The Chinese model has faced increasing scrutiny regarding debt sustainability, procurement transparency, and local economic spillovers. Nevertheless, it remains prevalent in many regions due to its perceived advantages in execution speed and financial accessibility. The model, however, is in constant evolution; structures now vary significantly by sector and partner, incorporating more diverse arrangements like co-financing and joint ventures. Whatever funding model is adopted, transforming financial resources into sustainable infrastructure requires more than sound architecture; it demands project preparation capacity, regulatory clarity, and a unified public strategy.

One of the most successful ports in the Mediterranean region is Tanger Med in Morocco, a state-led strategic infrastructure platform combining public investment, MDB financing, and competitively awarded private concessions. The project was developed under the leadership of a dedicated public agency (the Tanger Med Special Agency), which ensured strong coordination between infrastructure and urban planning, industrial development and logistics integration. Core port infrastructure, including breakwaters, access channels and basin development, was financed primarily through public resources and long-term loans from MDBs, namely the EIB and the WBG. This public investment created the enabling platform for private participation. Terminal operations were subsequently awarded through competitive concession agreements to leading international private operators (i.e., APM Terminals, part of Maersk), which financed

and managed terminal infrastructure and equipment.

The success of Tanger Med underscores the vital role of institutional coherence over mere financial structuring. Its performance stems from a long-term strategic vision that integrated port operations with industrial and logistics zones, creating a robust policy anchor. By sequencing public investment before private concessions, Morocco effectively aligned commercial risks with operational expertise, while multilateral funding bolstered the project's credibility. Building on these lessons, the following sections analyse how private funding is mobilised for transport infrastructure in developing countries.

Public-Private Partnerships (PPPs) and risk-sharing instruments in transport infrastructure

While sovereign financing remains the dominant model for transport infrastructure in the 5 South Med countries, private participation has played a more selective and context-dependent role. Evidence from the region and comparable markets suggests that PPP structures are not uniformly applicable across all transport segments and require careful consideration of project characteristics, demand profiles and institutional capacity. Private participation in the 5 South Med countries' transport sector remains limited and uneven over time, typically focused on specific large-scale concessions and in port and logistics segments, as is the case in Morocco.

Private investments concentrate where relatively predictable revenue streams are, where demand risk can be reasonably assessed. In transport, PPP structures have been applied in ports, airports, toll roads, rail freight terminals and logistics platforms, although their success varies significantly across sectors and projects. Under a PPP arrangement, a public authority grants a private consortium the right to finance, construct and operate an infrastructure asset for a defined concession period (World Bank, 2017).

Empirical evidence indicates that PPPs in transport are particularly sensitive to demand uncertainty and macroeconomic volatility. This is consistent with the operational experience of the World Bank, which notes that "demand risk is usually the most significant risk in PPP projects where revenues depend on usage" (World Bank, 2017). This assessment reflects accumulated evidence from PPP transactions and advisory work across multiple regions, supported by project finance literature and case-based experience in sectors such as toll roads, ports and airports.

Port terminals frequently operate under concession agreements that allow private operators to finance, build and operate terminal facilities in exchange for the right to collect user fees during a defined period. These arrangements involve the creation of a special purpose project company that raises financing through a combination of equity investment and long-term debt. A typical capital structure for a port PPP may include approximately 20-30% equity, 60-70% senior debt (i.e., a class of debt that has priority over all other unsecured or 'junior' debt), and a smaller tranche of subordinated debt or mezzanine financing (Yescombe & Farquharson, 2018). Infrastructure investment funds and global port operators are increasingly active in such projects because port operations often generate relatively stable revenue streams, especially when supported by strong trade flows and competitive logistics positioning.

Yet, PPPs do not emerge spontaneously. Their success depends on well-prepared tender processes, bankable concession contracts, clear risk allocation and credible procurement frameworks. This is particularly important in countries where governments may lack the technical expertise required to structure complex concession transactions.

The IFC has developed a specialised advisory model to address this challenge (IFC, n.d.). Through its Transaction Advisory Services, the IFC supports governments throughout the PPP lifecycle: from project identification, feasibility studies and financial modelling to concession contract design, tender preparation, competitive bidding and financial close (IFC, 1999). Once the concession has been awarded, the IFC may also participate in the financing of the project, either through direct lending or through the mobilisation of commercial banks. This integrated model has contributed to the IFC's capacity to support the structuring of PPP transactions in developing countries, combining advisory services, financing and private investor mobilisation within a single operational framework. This reduces private investor uncertainty and strengthens the credibility of the procurement process.

The IFC, EBRD and EIB all support infrastructure PPPs, but their operating models differ in terms of emphasis and institutional mandate. While the IFC offers a particularly integrated model, the EBRD adopts a more policy-driven approach, fostering PPP legal frameworks and reform processes, but providing only limited transaction advice. The EIB focuses more on sovereign and project finance, complemented by advisory support through instruments such as the EIB Advisory Hub and other technical assistance facilities. It must be noted that instruments such as JASPERS, ELENA or EPEC are primarily designed for EU member states and are not directly applicable in the 5 South Med countries. This difference in institutional posture helps explain why many non-EU projects financed by the EIB remain sovereign loans rather than privately financed concessions.

The viability of PPP structures depends critically on the allocation and mitigation of risks between public and private actors. Infrastructure investments in emerging markets face risks that can discourage private participation, including political uncertainty, regulatory instability, currency convertibility risk, demand volatility, and construction and completion risk. MDBs have therefore developed instruments to improve creditworthiness and facilitate private investment.

These include WBG guarantee instruments (MIGA), namely so-called political risk guarantees, which protect lenders against losses from government non-compliance with contractual obligations, and the partial credit guarantees (PCGs), which improve project creditworthiness by covering part of debt service, thus extending maturities and reducing borrowing costs.

Pure 'demand risk guarantees' are rare, instead, governments use mechanisms such as minimum revenue guarantees (MRGs), which compensate private concessionaires when traffic or revenues fall below agreed thresholds, or availability payments, which remunerate private operators for providing infrastructure rather than exposing them fully to demand risk. Revenue floors combined with risk-sharing provisions may further align incentives between public authorities and private operators.

Alongside these instruments, MIGA provides long-term (15-20 years) political risk insurance (PRI), covering expropriation,

breach of contract, transfer restrictions, political violence, and civil disturbance, critical for infrastructures such as ports, railways and logistics corridors, where revenues depend on long-term trade flows, and political or regulatory uncertainty can deter investors. With guarantees, risks are mitigated and credit quality improves, maturities lengthen, and equity returns become more predictable, which is why guarantee-backed structures have played a critical role in projects such as Queen Alia Airport in Jordan, the Dakar Container Terminal concession, and Azura Power in Nigeria, combining WBG financing with partial risk guarantees (IFC, 2015).

Therefore, targeted project preparation facilities, combined with risk-sharing instruments such as guarantees, can play a catalytic role in enabling private participation where appropriate, while ensuring that financing structures remain aligned with long-term public policy objectives.

Structural challenges in transport PPPs: lessons from port and other infrastructure sectors

While ports provide some of the most visible examples of PPPs in transport, similar structural challenges can be observed across a broader range of assets, including toll roads, rail concessions and logistics platforms. The discussion below uses port PPPs as an illustrative case, while highlighting issues that are generally relevant to all transport infrastructures involving private participation.

Ports are often considered suitable candidates for PPP structures due to their potential to generate user-based revenues and benefit from trade growth, although actual performance depends on a range of external and project-specific factors. A frequently observed challenge is over-optimistic traffic forecasts. Projections often assume stable growth in GDP, trade and logistics patterns, but port demand is highly sensitive to global trade cycles, shipping alliances, regional competition and geopolitical shocks. Traffic can shift suddenly if alliance structures change or if a competing hub expands. Another common constraint relates to inter-port competition. Ports do not operate in isolation. A concession may be structured around certain throughput assumptions, but nearby facilities such as Tanger Med, Algeciras, Valencia or Port Said may expand capacity and capture traffic.

In some cases, concessions included relatively high upfront fees or revenue-sharing mechanisms, which may affect long-term financial sustainability. Governments sometimes attempt to maximise upfront revenues through high concession fees or revenue-sharing requirements, undermining operators' financial resilience. For this reason, the IFC and other institutions increasingly prioritise investment commitments and bankable structures over headline concession fees. A fourth problem is currency risk. In many developing countries, revenues are generated in local currency while debt is denominated in euros or dollars, making projects vulnerable to depreciation unless properly hedged. A further challenge is political interference, as governments may impose tariff caps, labour rules or regulatory changes, increasing uncertainty and perceived risk for investors.

These considerations highlight the importance of careful project selection, realistic demand assessment and balanced risk allocation in the design of PPPs. They also reinforce the broader conclusion that private participation in transport infrastructure

can be effective under appropriate conditions, but requires strong institutional frameworks, robust financial structuring and credible regulatory environments to deliver sustainable outcomes. When those conditions do not materialise, a simpler sovereign financing structure remains inevitable.

Syndicated loans, capital markets and the construction-to-bond model

Capital markets are an increasingly important source of long-term funding for infrastructure financing, attracting institutional investors such as pension funds and insurance companies seeking stable, long-duration assets. However, their role differs significantly from that of syndicated loans. A syndicated loan is a large-scale financial arrangement where a group of lenders, known as a syndicate, collectively provides funds to a single borrower under a single set of terms and conditions. This structure is primarily used for substantial capital needs that exceed the risk appetite or financial capacity of any one individual lender.

During the construction phase of complex infrastructure projects, syndicated loans remain the preferred financing instrument. They provide flexibility because loan agreements can be renegotiated if unexpected events occur during construction. Infrastructure projects frequently face engineering delays, cost overruns, contractual disputes or slower-than-expected demand (Flyvbjerg, 2017). Syndicated loans allow banks to renegotiate covenants, extend maturities or grant temporary waivers, making them particularly suitable for greenfield transport projects. By contrast, capital markets are better suited to assets in operation. Once infrastructure is built and revenues stabilise, bonds can then provide long-term funding at attractive cost (UNCTAD, 2022).

For this reason, many projects adopt what is known as a construction-to-bond refinancing model: construction is financed through syndicated bank loans and sponsor equity. Once operational, debt is refinanced through bond issuance. This allows banks to recycle capital into new projects while enabling long-term investors to participate in mature infrastructure assets.

The WBG has also developed instruments designed to facilitate infrastructure bond financing. The IFC's PCGs can cover principal and interest on corporate bonds from infrastructure projects and provide liquidity during cash-flow disruptions. The WBG has also explored infrastructure bond liquidity facilities to support capital market financing. However, even with guarantees, bonds remain less flexible than bank loans during the construction phase. As a result, the construction-to-bond refinancing model remains the most widely used structure for complex infrastructure investments. This model can be equally relevant for the 5 South Med countries.

The Blue Mediterranean Partnership: a regional investment platform for the Blue Economy

As evidenced in previous sections, experience across sectors indicates that the most effective investment approaches combine project preparation support, capacity-building and access to financing within integrated frameworks. Several initiatives illustrate this model in practice. Within the Mediterranean context, the Blue Mediterranean Partnership (BMP) repre-

sents one relevant example, namely in the blue economy domain. The BMP provides an illustration of how Global Gateway priorities can be translated into operational investment pipelines, transforming strategic objectives into bankable projects.

Launched as a regional investment platform, the BMP aims to mobilise financing for sustainable blue economy investments in the southern shore of the Mediterranean. The initiative reflects recognition that many potentially transformative infrastructures fail to reach the financing stage due to insufficient project preparation capacity. It therefore combines project preparation support with concessional financial resources and development bank financing, creating an investment pipeline capable of mobilising large-scale investments. While the BMP is focused on the blue economy, similar integrated approaches are increasingly relevant for transport infrastructure, where project preparation constraints and financing gaps remain key barriers to investment.

The initiative is implemented by several European development finance institutions, with the EBRD and the EIB as the principal implementing partners. The EBRD also administers a multi-donor trust fund, currently around €30 million, sponsored by European sovereign partners and the European Commission, used to provide concessional resources to finance feasibility studies, technical assistance, and advisory services for project preparation. The initiative encourages all countries in the Southern Mediterranean to submit investment projects that fit their own development strategies and sectoral goals. Among those under preparation is a programme to green Moroccan port infrastructure, focusing on emissions reduction, energy efficiency, and environmental sustainability. Other countries, including Egypt and Jordan, have already joined the initiative.

From a policy perspective, the BMP offers an operational platform through which 5+5 Dialogue countries can strengthen their engagement in sustainable infrastructure investment. On the northern shore, European countries not yet involved could consider joining as donors or implementing partners, reinforcing both the financial capacity and geographical scope of the initiative. Their participation would expand concessional resources while strengthening technical expertise and institutional coordination within the region. The BMP framework offers scope to deepen structured North-South cooperation through targeted capacity-building, joint project preparation and the exchange of technical expertise. This would reduce asymmetries in project preparation capacity and support a more balanced and integrated regional investment ecosystem.

On the southern shore, 5+5 countries are encouraged to take the institutional steps required for future adhesion as beneficiaries. This includes strengthening national project pipelines, enhancing coordination between sectoral ministries and financial institutions, and aligning national investment strategies with blue economy and climate resilience priorities.

More broadly, initiatives such as the BMP highlight the potential of regional project preparation and financing platforms in bridging the gap between strategic policy objectives and bankable investments. By linking project preparation, concessional finance and development bank lending, such approaches can contribute to strengthening investment ecosystems across sectors, in-

cluding transport infrastructure, where similar structural challenges persist.

Conclusions and Recommendations

This article highlights that the future of transport in countries participating in the 2026 GTMO 5+5 Ministerial Conference of Transport depends on the creation of investment ecosystems capable of mobilising diverse capital. To transform fragmented project pipelines into investable infrastructure systems, the following six strategic actions are identified:

A. **Transitioning to integrated investment ecosystems.** The evolution of European external policy, notably through the EFSD+ and the Global Gateway, signals a shift toward blending public finance with development bank lending and private capital. Future frameworks must move beyond isolated funding toward these integrated structures to effectively close infrastructure gaps and bolster climate resilience.

B. **Deploying operational regional investment platforms.** There is a critical need for regional platforms that act as operational interfaces between project promoters and financial institutions. Building on models like the BMP but extending them to the full transport sector and other strategic areas, these platforms should use concrete projects as the starting point to identify and resolve regulatory bottlenecks and market failures, effectively turning policy goals into tangible results.

C. **Institutionalising dedicated project preparation facilities.** Yet financial instruments alone will not be sufficient. Strengthening project preparation capacity, improving regulatory frameworks, and developing credible PPP structures remain essential conditions for attracting long-term institutional investors. A Mediterranean project preparation facility paired with guarantee mechanisms could unlock significant private investments.

   A primary barrier to investment is the lack of bankable projects. Establishing technical facilities inspired by existing European instruments but tailored to the 5 South Med countries context is essential to professionalise feasibility studies and PPP design. These hubs ensure that projects reach international standards requested by financing institutions from their earliest stages, creating a direct pipeline from conception to preparation to investment.

D. **Synchronising regional planning and institutional coordination.** To maximise economic returns and optimise project prioritisation, infrastructures must be assessed through network effects rather than as isolated assets, building on the 5+5 Dialogue and existing corridor mapping initiatives. Aligning national investment strategies with a shared regional vision for transport corridors is vital. This includes improving cooperation between line ministries, planning agencies, and financial institutions. This also requires standardising procurement and appraisal procedures across borders to build the regulatory predictability that institutional investors require.

E. **Embedding climate resilience and data harmonisation.** In an era of increasing climate risk, planning must move from a project-based ap-

proach to system-level resilience. This implies not only strengthening individual assets, but also ensuring redundancy, interconnectivity, and operational flexibility across transport networks. Adopting harmonised performance indicators and integrating so-called avoided disruption costs into project appraisals will not only protect assets but also increase access to international green and climate financing by improving the alignment between investments and long-term climate adaptation objectives.

F. **Fostering peer-to-peer capacity-building.** To ensure an inclusive and integrated investment space, the region must systematically share technical expertise. By embedding capacity-building into regional platforms, countries with more mature frameworks can help reduce technical asymmetries, ensuring a more competitive and cohesive Mediterranean market.

The successful and ultimate transformation of the Western Mediterranean transport sector depends on the alignment of financial innovation with institutional reform. By adopting these six pillars, the countries of the 5+5 Dialogue can accelerate the transition toward a sustainable, connected, and resilient regional economy that effectively mobilises both public and private capital.

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CONCLUDING REMARKS

IEMed and CETMO

The contributions gathered in this Policy Study paint a clear picture of a Western Mediterranean region at a critical juncture. Climate change, geopolitical instability, technological transformation, and shifting economic relationships are reshaping both the transport sector and the broader development pathways of countries across the basin. Whether for better or worse, the transformation of the transport sector in the 5+5 countries is no longer a future prospect; it is already underway.

As Imed Zammit highlights, the Mediterranean is warming faster than the global average and faster than many other open seas (see Cusack and Cox, 2025). These environmental pressures are unfolding in a region that serves as a vital corridor for global maritime trade and whose economies remain deeply reliant on the movement of goods, energy sources, and people. The resulting paradox is stark. As Zammit observes, maritime transport is indispensable to the economic development of Mediterranean economies and to Euro-Mediterranean trade; yet it is also a major driver of greenhouse gas emissions and environmental degradation, both of which can undermine port areas through increased climatic risks.

Sergi Saurí further explores how climate change is already affecting infrastructure, logistics networks, and mobility patterns. Rising temperatures are accelerating the deterioration of roads, railways, and airport infrastructure. Shifts in precipitation patterns are affecting waterways and agricultural production, with implications that extend well beyond transport. Extreme weather events, including floods, storms, droughts, and wildfires, are increasingly disrupting transport operations and supply chains. Sea level rise adds further pressure on ports and coastal infrastructure, requiring substantial investment in adaptation and resilience.

Yet climate change is only one source of disruption; geopolitical tensions are reshaping transport networks and exposing new vulnerabilities. As Saurí and Zammit note, tensions such as those in the Red Sea and the Suez Canal have rerouted shipping flows, increased costs, extended transit times, and altered the competitive position of Mediterranean ports. While some ports in the Western Mediterranean, including Barcelona, Valencia, Algeciras, Tanger Med, and Marsaxlokk, have benefited from these disruptions, others in the Easter Mediterranean, such as Port Said, Piraeus and Gioia Tauro, have faced growing uncertainty. As Saurí notes, the effects have not been limited to the Mediterranean basin, with maritime and inland logistics chains in Europe and North Africa also affected (see UNCTAD, 2024).

Together, these developments underscore that strengthening the resilience of the transport sector is not only about confronting climate change, but also a geopolitical and economic imperative. The ability of transport systems to adapt to overlapping shocks will increasingly determine regional competitiveness and stability. In this context, the transport sectors of the 5+5 countries face a dual challenge: adapting to an increasingly complex landscape of climatic, environmental, and geopolitical disruptions while accelerating emissions reductions to curb the very risks that make climate adaptation necessary in the first place.

Nora Aboushady provides a comprehensive overview of transport decarbonisation pathways available to the Western Mediterranean. Electrification, renewable energy deployment, hydrogen development, synthetic fuels, and digitalisation all emerge as critical components of a transition in a sector already responsible for one quarter of global greenhouse gas emissions (see ITF, 2024). However, the adoption of any of

these pathways, along with the alternative fuels they require, does not come without its trade-offs. As Zammit illustrates, alternative maritime fuels such as liquefied natural gas, green methanol, hydrogen, ammonia, and biofuels each come with distinct advantages and limitations in terms of cost, emissions, availability, storage requirements, and compatibility with existing fleets.

These trade-offs are especially important to consider in a region characterised by markedly uneven capacities to decarbonise and adapt transport systems, and where persistent North-South inequalities may constrain the overall potential of the region's transport transition, a concern that emerges repeatedly across several papers in this collection. For example, Saurí highlights the asymmetry in North-South trade flows, with the Maghreb exporting large volumes of raw materials and energy commodities through bulk cargo; while Southern European countries export lower volumes but higher value finished goods (see Selfa, 2024). Aboushady highlights significant differences in regulatory capacity and governance frameworks. While Northern Mediterranean countries benefit from dense policy architectures and financial instruments linked to the European Green Deal, Fit for 55, the Trans-European Transport Network (TEN-T), and the Connecting Europe Facility, which enable sustained investment in rail, ports, electrification, hydrogen infrastructure, and digital systems, many Southern Mediterranean countries remain constrained by limited fiscal space, weaker institutional capacity, fragmented governance, unequal access to technology, and data gaps.

These dynamics are further developed in Jérôme Verny and Ouail Oulmakki's contribution, which places ports at the centre of the analysis. Through the cases of Tanger Med and Barcelona, they show how ports are no longer merely gateways for trade but strategic platforms where energy systems, logistics networks, digitalisation, and geopolitical competition increasingly converge. Projects such as BarMar - a 400 kilometre subsea pipeline connecting the ports of Barcelona and Fos-sur-Mer in southern France - further illustrate this shift, positioning ports as critical nodes in Europe's emerging hydrogen economy. Crucially, Verny and Oulmakki also caution that this transformation is not automatically redistributive. Emerging green value chains risk reproducing existing North-South asymmetries, with Southern Mediterranean countries positioned primarily as suppliers of renewable energy and green molecules, while higher value-added industrial functions remain concentrated elsewhere. Ports may therefore evolve into advanced hubs without necessarily altering underlying patterns of value capture. This raises a central question for the transition: whether green industrialisation will fundamentally reshape Mediterranean economic geography or instead repackage existing hierarchies in new technological forms.

Aboushady reinforces this concern by pointing to a broader paradox, in which decarbonisation reduces dependence on fossil fuels but may simultaneously generate new dependencies on imported technologies, digital systems, investment flows, and external markets. Her call for a just transition within and between countries serves as a warning against reinforcing a model of clean energy export enclaves in the South that primarily serve Europe's needs (see Aboushady and Faus Onbargi, 2023). This requires, among other actions, closing existing gaps in governance capacity, technology and, crucially, finance.

While mitigation has historically dominated investment flows, especially in the energy

sector and in coal in particular as one of the most cost-effective sites for transition (see Malerba, 2022), the adaptation of transport systems is equally urgent. Roads, railways, ports, and airports were designed for climatic conditions that can no longer be assumed to hold, making adaptation less a one-off investment cycle and more an ongoing process of infrastructure redesign and continual adjustment, as Juan Alario and Joan Ignasi Alario Piedra write in their article.

The scale of the challenge is substantial. Estimates suggest that adaptation financing requirements in the transport sector will require €7-8 billion per year by mid-century in the European Union (EU), and significantly more under a high-warming scenario (see EEA, 2025). Yet one of most striking findings by the authors is the limited knowledge base currently available on adaptation needs in the sector across the 5+5 countries. Reliable estimates remain scarce, particularly in the Southern Mediterranean. Even within the European Union, only a limited number of countries have undertaken comprehensive assessments of transport adaptation financing requirements. This creates a major governance challenge: policy-makers are increasingly required to make long-term resilience decisions under conditions of significant uncertainty regarding costs, benefits, and investment needs.

Alario and Alario focus on how adaptation investments should be assessed and prioritised, based primarily on economic profitability (though this does not forego other criteria). Their contribution highlights the growing importance of integrating climate risk assessment, economic appraisal, and uncertainty analysis into investment decision-making. Adaptation planning increasingly requires not only an understanding of future climate hazards but also robust methodologies for comparing intervention costs with the social and economic damages they help avoid. Such approaches are becoming essential for multilateral development banks and other financing institutions seeking to prioritise investments under constrained resources and deep uncertainty.

In the final paper of this Policy Study, Andrea Tinagli situates these financing challenges within a broader investment ecosystem. He argues that official development assistance and concessional finance, while important, are insufficient relative to the scale of need. Mobilising adequate resources requires layered financing architectures combining multilateral development banks, private capital, syndicated finance, public private partnerships, and risk-sharing instruments. In this context, he highlights the European Union's Global Gateway initiative as an emerging coordination framework rather than a standalone funding instrument. By linking investments in transport, energy, and digital connectivity across the Mediterranean, Global Gateway is helping to shape infrastructure corridors and development pathways where sectoral boundaries increasingly blur.

At the same time, Tinagli warns that the European Union is only one actor among many. The growing presence of Chinese infrastructure financing reflects a broader reconfiguration of global investment patterns, where differences between actors lie not only in capital volumes but also in governance standards, procurement models, and environmental and social safeguards. These choices increasingly shape not just individual projects, but the institutional architecture of Mediterranean development itself.

Beyond the availability of financial resources, the preparation of bankable projects emerges as one of the principal

constraints on investment mobilisation across the Western Mediterranean. Strengthening project preparation capacities, technical expertise, and institutional readiness will therefore be essential to transform strategic priorities into investable infrastructure pipelines. In this context, regional platforms combining project preparation, technical assistance and access to finance can play an important role in bridging the gap between policy objectives and implementation, while fostering greater cooperation and knowledge-sharing across the region.

Overall, the contributions in this Policy Study highlight that the transformation of transport in the Western Mediterranean is already underway. While decarbonisation and adaptation are advancing across fuels, infrastructures, and governance systems, the evidence presented here shows that these transitions can be highly uneven in both capacity and outcome, with persistent asymmetries in finance, technology, and institutional strength shaping who benefits and who bears the costs. Financing emerges as a decisive constraint and political lever, as adaptation and mitigation needs increasingly exceed available resources and require new forms of coordinated investment under conditions of uncertainty. One central challenge, therefore, is not only to accelerate the transport transition, but to ensure that it reconfigures rather than reproduces existing regional hierarchies across the Mediterranean.

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