LOGISTICS IN TRANSITION

Exploring Geopolitical, Economic, and Technological Trends

edited by **Carlo Secchi** and **Alessandro Gili**

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Logistics in Transition. Exploring Geopolitical, Economic, and Technological Trends

Edited by Carlo Secchi and Alessandro Gili
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This study is an initiative of the ISPI's Centre on Infrastructure, promoted with the knowledge partnership of McKinsey & Company. The Centre on Infrastructure focuses on how geopolitical and economic trends shape and are shaped by investment decisions on infrastructural projects. It aims to analyse global trends (new technologies, mobility, sustainability, etc.) and monitor major projects, also with a view to gauging their complementarity/competition and financing channels. Specific attention is devoted to the role of key economic and political players at all levels – from local to global – including regional and international development banks, whose "political" agenda is often crucial to foster public and private investment.

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Introduction

In recent years, the ISPI annual Report on Infrastructure, developed in partnership with McKinsey & Company, has delved into a broad spectrum of issues. These range from the financial and structural conditions fostering infrastructure development to emerging themes like sustainability and digitalization, both recognized as pivotal for greening and enhancing the efficiency of infrastructure. Last year, our analysis centered on resilience, exploring how infrastructure serves as a critical asset in establishing more resilient global and regional value chains. We examined how infrastructure could be designed, constructed, and maintained to ensure greater resilience and durability. These themes collectively underpin the broader issue of facilitating a more efficient movement of people and goods, including raw materials and food, while considering enterprise costs and strategies.

Logistics plays a prominent role in international economic affairs, especially in the current context. This report aims to explore this role from various perspectives, including geopolitics, economics, technology, digitalization, and environmental issues. One section will examine the infrastructure and logistics strategies of the world's most significant regions and countries. Additionally, the volume is enriched with selected case studies focused on the Italian situation and various types of logistics platforms.

Over the past few years, global logistics has undergone significant upheavals and transformations. Events such as Brexit, the Covid pandemic, the war in Ukraine, and more recently, the Red Sea crisis triggered by the Israel-Gaza conflict, have served as pivotal geopolitical junctures. Additionally, escalating geopolitical tensions between Western nations on one side, and China and Russia on the other, have placed further strain on already intricate global value chains.

These disruptive events have prompted a gradual restructuring of global value chains, with major global corporations and advanced Western economies pursuing de-risking strategies aimed at mitigating risks and bolstering the resilience and security of their supply chains. This imperative is particularly pronounced for critical technologies like clean tech and advanced semiconductors, which underpin contemporary industrial production. Processes such as re-shoring, near-shoring, and friend-shoring are shaping a new era of globalization, characterized by the diversification and regionalization of trade flows among like-minded and geopolitically aligned nations. Deglobalization presents significant challenges for the strategies and operations of companies that are reflected in the need to revise their value chains, both to try to contain costs and from a logistical point of view. In this context, logistics plays a pivotal role in facilitating the effective and successful restructuring of value chains amid rapidly evolving dynamics.

Moreover, these trends have been underscored by the occurrence of disruptive events, previously deemed improbable, such as Houthi attacks. Furthermore, non-geopolitical factors like climate-related disruptions are impacting global maritime chokepoints, as evidenced by the situation at the Panama Canal. Nearly 50% of traffic through the Panama Canal dropped in 2024 compared to peak levels, primarily due to severe drought in the region. Similarly, the grounding of the Evergrande container ship in the Suez Canal in 2021 highlighted the fragility of global value chains and the necessity of shortening them. Overall, logistics has proven to be more susceptible than anticipated to the effects of climate change. For instance, the Frejus landslide in August 2023 compromized the railway link between France and Italy, significantly disrupting freight traffic between the two countries, which has largely been redirected to other modes of transportation or alternative routes. In addition, the consequences of these climate-induced disasters were further exacerbated by the incident that occurred in the Gotthard Tunnel in August 2023. Globally, wildfires and floods are becoming increasingly frequent, exerting detrimental effects on the functioning of logistics and transportation infrastructure.

Against this backdrop, the leading Western economies, as mentioned earlier, have embarked on industrial strategies aimed at fortifying their industrial base and winning back increasing shares of industrial output in critical sectors. This objective underpins initiatives such as the US Inflation Reduction Act of 2021, the US and EU Chips Acts, and the EU Net Zero Industry Act. However, for these strategies to succeed, they must be supported by robust infrastructure that facilitates internal, regional, and global connectivity, as well as overall economic competitiveness. Strong infrastructure is indeed a prerequisite for the effective reshaping of logistic strategies. This rationale underscores the main infrastructure plans adopted by many Western economies, partially also in response to the Chinese Belt and Road Initiative

The US Infrastructure Investment and Jobs Act of 2021, for instance, authorized $1.2 trillion for transportation and infrastructure spending, with $550 billion earmarked for "new" investments and programs. In 2022, the G7 launched the Partnership for Global Infrastructure and Investment (PGII), a $600 billion plan to promote connectivity and sustainable infrastructure in emerging economies and developing countries. Within this comprehensive framework, the EU introduced the Global Gateway, a $300 billion initiative aimed at enhancing Europe's connectivity with the rest of the world, with a particular focus on Africa.

Most recently, on the sidelines of the 2023 G20 Summit in New Delhi and in the framework of the PGII initiative, G7 countries endorsed a new plan for an India-Middle East-Europe

Corridor (IMEC). The project is envisioned to include both a maritime and a land corridor. The maritime track would link Indian ports to the United Arab Emirates, while the land corridor would cross Saudi Arabia to reach the ports of Israel, facilitating the movement of freight toward the northern shore of the Mediterranean. However, escalating tensions in the region, particularly in the context of the Israel-Gaza conflict, pose a significant challenge to the project's actual feasibility.

Europe has faced significant challenges arising from both internal and external shocks in recent years. It began with Brexit, which has led to trade relations becoming weaponized and has complicated freight transport and border procedures between the UK and the EU, as well as between the UK and Ireland. Brexit particularly undermined the UK landbridge, which is the route connecting the Republic of Ireland to the rest of the EU via mainland Britain's road and port networks, prompting a swift reassessment of Irish logistics, including modal shifts.

The pandemic has further disrupted value chains within the EU and between European countries and the rest of the world. It has highlighted the vulnerabilities inherent in the just-in-time manufacturing paradigm, which, while aimed at maximizing efficiency and cost savings, can strain global logistics and value chains during sudden shocks, leading to delays and significant disruptions.

The war in Ukraine has dealt another blow to European value chains, exposing the inherent fragility of European supplies, particularly concerning raw materials, agricultural products, and other strategic commodities. The swift establishment of Solidarity Lanes – alternative logistics routes utilizing all relevant transport modes – has been crucial for maintaining the import and export of critical goods to and from Ukraine.

The Israel-Hamas conflict, coupled with Houthi attacks on Western container ships, has further disrupted European supply chains, leading to increased costs and delivery delays. Indeed, the attacks resulted in the reduction of over 40% in the traffic of vessels through Bab-el Mandeb and the Suez Canal, which accounts for 12% of global trade and 30% of global container traffic. Consequently, container ships have rerouted via the Cape of Good Hope, with longer and more expensive journeys. Moreover, a prolonged crisis could result in GDP costs, higher inflation for Europe, and decreased traffic for Mediterranean ports.

In this rapidly evolving landscape, Europe has acknowledged its logistical weaknesses, particularly in terms of multimodality, and is undergoing reforms to bolster efficiency, competitiveness, and resilience also in the face of climate change. These issues lie at the heart of the new TEN-T Regulation recently approved, which seeks to enhance the safety, sustainability, speed, and convenience of the EU's transport network for its users. According to the Regulation, greater emphasis should be placed on modal shift, rail travel for passengers and the transportation of goods, inland waterways, and short-sea shipping.

Furthermore, the new Regulation places significant emphasis on the role of urban nodes in improving mobility, both in terms of sustainability and efficiency. Urban centers are encouraged to adopt Sustainable Urban Mobility Plans (SUMP) to facilitate the movement of their residents and to establish multimodal logistical platforms to enhance freight logistics.

Additionally, Europe is actively working to strengthen and diversify its international connectivity with Asia. The Middle Corridor, for example, has been identified in a recent study by the European Bank for Reconstruction and Development (EBRD) on behalf of the European Commission as the optimal route to connect Europe with Central Asia, with recommendations for integration into the European TEN-T networks.

In Italy, there is widespread recognition of the need for an enhanced logistics strategy, particularly in integrating Italian ports, main highways, and railways into the TEN-T network. Simultaneously, it is crucial to bolster multimodal logistic platforms and overall infrastructure to enhance the competitiveness of Italian logistics and ports, especially in the Mediterranean region. Given this context, the Italian

Ministry for Infrastructure and Transport has tasked its in-house company RAM with implementing a National Platform for Digital Logistics (PLN). This initiative is anchored on four primary pillars: interoperability, reuse, management autonomy, and security.

At the global level, sustainability also stands out as a major game-changer. The entire logistics sector is experiencing profound transformations: modal shifts are altering the distribution of global freight and the overall significance of logistics platforms. These platforms have become the backbone and vital facilities complementing the activities of port infrastructures and major urban hubs. Firstly, they play a crucial role in sorting freight and goods for transportation by railways and highways. Secondly, they are essential for regaining profitability and generating economies of scale by offering new services, such as initial processing stages, amidst escalating international competition among ports.

Additionally, new legislation is being introduced in advanced economies to curb logistics emissions. In the European Union, for instance, the "Greening Freight Transport" package aims to slash emissions from the transport sector by 90% by 2050, by advocating for the use of sustainable fuels, promoting railway transportation and short-sea shipping routes, integrating the maritime sector into the Emission Trading System (ETS) Framework, together with the Carbon Border Adjustment Mechanism (CBAM).

Increasing digital logistics capabilities can yield significant benefits in terms of cost reduction and service delivery enhancement, thereby improving operational performance, sustainability, customer satisfaction, and, in certain cases, revenue generation. On the operational front, digital tools can optimize logistics throughout the planning, execution, and settlement phases. Leading logistics players are already experiencing performance improvements of 10 to 20 percent in the short term and anticipate gains of 20 to 40 percent within two to four years. Moreover, AI is increasingly valuable for designing and optimizing logistics networks, as well as streamlining automated warehouse operations and enhancing customer experiences. Particularly in ports, AI tools play a crucial role in estimating ship arrival times and cargo availability, thereby optimizing turnaround activities and container movements.

Industries, trade, and logistics are adapting to rapidly evolving geopolitical and economic dynamics. Europe finds itself at a crucial moment and must define its next steps towards integration to foster economic and political effectiveness. The Report presented in April 2024 by Enrico Letta ("Much More Than a Market") and the forthcoming Report of Mario Draghi on EU competitiveness underscore the urgent need for decisive actions to ensure Europe's efficacy in a changing world. Logistics and infrastructure play a crucial role in this endeavor, as acknowledged by the G7 Transport Ministers Meeting held in Milan from 11 to 13 April 2024. The G7 Transport Ministers emphasized the heightened importance of bolstering the resilience, shock-resistance, and adaptability of transport systems in light of the convergence of multiple crises. They acknowledged that transport connectivity enhances labor markets, facilitates the matching of demand and supply of skills and capabilities, and facilitates global value chains and the economic productivity they entail.

International cooperation is paramount for building global connectivity and resilient logistic systems. Geopolitical shifts and climate change pose challenges that could disrupt the effective functioning of logistics. This underscores the need for policymakers and operators to implement mitigation measures that also enhance the security of supplies. Amidst global turmoil, diversification and redundancy of transportation systems and modes are crucial, with the security of supplies serving as the backbone for the smooth functioning of the global economy. If it is true at the global level, it is even more important in the European Union, with a long-standing history of openness and free trade.

Carlo Secchi, Alessandro Gili

1. Supply Chains, Chokepoints, Ports and International Logistics: A Geopolitical Challenge

Alessandro Gili, Enrico Paolo Gioia, Roberto Italia

This chapter will be published in the final version of the Report.

2. New Scenarios in International Transportation and Global Value Chain Transformation

Oliviero Baccelli

International transportation has historically been the thermometer of world economies, particularly over the past two decades, i.e., since China has forcefully entered the global value chains of all major sectors. The past four years have been characterized by the overlapping of different types of crises capable of affecting international transportation: geopolitical crises (due to the conflicts in Central and Eastern Europe and the neighboring Middle East), social crises with important migratory phenomena due to growing economic imbalances, and climatic crises, to which must be attributed the disasters caused by floods capable of seriously compromising strategic transport infrastructures, but also believed to be the cause of the restriction of the Panama Canal crossing, or of having made the navigation of Central European rivers complicated, as well as being responsible for the sudden changes in the agri-food chain.

From the crises comes profound uncertainty that certainly justifies the many difficulties in being able to present clear scenarios for trade interchanges for 2024. These difficulties are well evidenced in the March 2024 Global Trade report prepared by UNCTAD, which shows the average 5% decline in the value of goods moved during 2023, mainly due to a reduction in trade between developing countries, albeit with strong differentiations between countries. For example, in 2023 the European Union recorded a 14% reduction in imports and a 2% increase in exports, while China recorded a -5% in both imports and exports, a figure similar to the United States with a -5% in imports and -2% in exports.

For 2024, UNCTAD expects the world economy to grow by 3%, although the year has opened under the banner of a sharp acceleration of geopolitical tensions in the neighboring Middle East and Central and Eastern Europe; an increase in the cost of shipping; and obvious difficulties in containing inflationary pressures with immediate effects on interest rates and consequent spillover effects on the economic outlook at higher levels of public and private debt. In addition, trade tensions between the United States and China add to the complexity of the analytical framework and make it more difficult to understand what the impact might be on firms most exposed to international markets.

The objective of this chapter is to provide summary insights to outline possible scenarios in the international transportation sector and global value chain transformations, with specific focus for Southern Europe. Above all, this area in fact is affected by two components of the previously listed crises that are characterizing these first months of 2024, that of the containerized traffic sector due to access restrictions to the Red Sea and that making Alpine crossings inefficient, resulting from closures and limitations for some of the main transport infrastructures.

The Containerized Shipping Market as a Litmus Test of International Crises

Partly due to the fact that about 50% of the goods transported in containers are linked to the organizational logics of intra-group exchanges between multinational companies, the containerized shipping sector, which is the thermometer of interchanges of semi-finished and finished goods, emphasizes the uncertainties in the scenarios.

The framework for analysis in this sector is made even more complex by the need to understand demand scenarios that are increasingly dependent on factors exogenous to the market, such as trade tariff policy made increasingly articulated by environmental policies or trade restrictions imposed by geopolitical choices, but also by the chaotic evolution of supply due to the strategic choices of a few large shipping companies, which have developed investments with diverse objectives among themselves over the past few years.

In order to better understand the effects of these turbulences in the sector, it is interesting to retrace the trends of one of the most relevant indices for trade relations between Europe and Asia, the Shanghai Containerised Freight Index (SCFI) based on Settled Rates (Export EUR Service). This index, updated weekly by the Shanghai Shipping Exchange, summarizes spot contract values for export shipments from China to Europe of a 20-foot container. This figure is influenced both by general trends in the global containerized shipping market, as vessel supply can be adjusted to demand needs through repositionings that take a few weeks, and by those of the specific route. The specificities of the route are due to the presence of numerous choke points (Strait of Malacca, Strait of Bab al-Mandab, Suez Canal, and Strait of Gibraltar) and the use of the largest capacity ships, with an average of 16,000 TEU and a maximum capacity of more than 23,000 TEU. This route therefore is the most sensitive to global value chain transformations, with high freight rate value volatility with inflationary consequences on major consumer goods imported to Europe from the Far East.

The SCFI Export EUR index remained around $1,500 per TEU during 2019 and for the first half of 2020, but as early as June 2020 the value rose to $2,000. The following months were characterized by continuous disruptions in supply chains due to both sudden closures of port terminals and logistics hubs due to Covid and increasing port congestion due to the operational impossibility of handling an increasing flow of imported goods. This demand development was related to the need to increase warehouse inventories to cope with uncertainties and to respond to the sudden increase in imported goods by consumers who, limited in their travel and ability to purchase services, have changed consumption behaviors in favor of goods such as furniture and electronic and household accessories. The 2022 data from the US Census Bureau, for example, showed record imports from China to the US and also record US exports to China, despite the US administration's specific industrial policies aimed at reducing dependence on China for critical supplies, including chips, with tariff enforcement. The year 2022 was also a record year for interchange between Europe and China, with +77% compared to 2012 in imports to Europe, bringing China to the top of the list of countries in terms of trade significance in European imports with a market share of 20.5%, and +45% in exports from Europe to China again compared to 2012, placing China third in Europe's final destination markets with a market share of 8.8%. The year 2023 saw a decline in both economic values, for a reduction in overall trade of as much as 27%.

The reflections on the value of the SCFI of such fluctuating trends were very rapid, with an increase to $5,000 in January 2021, a subsequent peak around $10,000 between September 2021 and January 2022, and a subsequent decline to $5,000 in September 2022 and a brief return to pre-Covid values throughout most of 2023. Beginning in the second half of December 2023, a further crisis led to renewed turbulence in the industry following attacks by Houthi guerrillas in the area of the Bab al-Mandab Strait at the entrance to the Red Sea, forcing most ships with Western interests to circumnavigate Africa via the Cape of Good Hope and lengthening travel times between Asia and Europe by 10-15 days. The operational result is the need to deploy about 10% of the entire container fleet to meet the demand resulting from the rearrangement of lines between Asia and Europe, which, instead of taking an average of 77-84 days for a full tourn round, take 98-112 days. Considering a total cost estimate (operating, investment and bunker consumption) for a vessel with a capacity of 20,000 TEU of about €130,000 per day means an increase in shipping costs of between €2.73 million and €3.64 million per voyage between Asia and Europe and back. Ports in the central and eastern Mediterranean suffer the most from this aspect, as they require the longest route lengths compared to the traditional route through the Suez Canal, and the first quarter data on containerized trades in Gioia Tauro, Malta and Piraeus clearly show this, marking -18%, -25% and -31% respectively.

Against this backdrop, the value of the SCFI rose to $3,500 on 20 December 2023, and then hovered around $3,000 during the first quarter of 2024, a value more than double that of the pre-pandemic period.

One of the results of the nearly two-year-long maritime freight bubble has been a change in the strategies of major shipping companies, which, on the strength of annual profits in 2021 and 2022 exceeding the sum of the profits generated in the previous twenty years, have developed strategies of vertical integrations with acquisitions of rail companies and logistics operators and placed particularly large orders for new ships. In particular, based on Alphaliner's indications, the fleet dedicated to container trades will increase by 9.8% in 2024 and 5.1% in 2025, i.e., values higher than the expected development of demand from international trade in semi-finished and finished products, leading to potential overcapacity. In fact, a fleet development of as much as 3.3 million TEUs is expected in 2024, 43% of which will be on ships with a capacity of more than 15,000 TEUs, with the market-leading company, MSC playing a leading role in more than 40% of this growth, with 1.3 million TEUs on order, after a record development of more than 1 million TEUs during 2023, amounting to +22% compared to fleet capacity in the previous year. This strategy of rapid development by MSC is not shared by Maersk, the second largest shipping company by capacity, which reduced its capacity by 2.7% during 2023. In summary, the two major companies have different views of development scenarios in the short and medium term.

MSC's expansive strategy has been rewarded by the sharp increase in freight rates during the early months of 2024 and has helped mitigate the effects of the crisis, which predictably would have been greater if all companies had pursued a strategy of reducing hold supply as in the case of Maersk.

The potential duration of the restrictions on the passage of the Bab al-Mandab Strait is unknown to any analyst as it depends on geopolitical factors arising from the ability of the very large front of Western and Asian navies to impose safe conditions on the passage of ships by dismantling the military capabilities of the Houthis strongly supported by Iran.

The Consequences on Global Value Chains of Crises in the Containerized Trade Market

Over the past four years, international transportation has gone from being a commodity with easily predictable characteristics and a low impact on final production costs, to being a source of new risks and with values capable of eroding a significant share of operating margins. This has challenged the close interdependencies between widely separated markets and forced a revision of the trade offs between cost/reliability/quality/timing, resulting in the need to adopt a new integrated strategic vision between production and transportation.

In fact, the continuous fluctuations in maritime freight rates, which are increasingly distant from values consistent with the 10-year time series of the pre-pandemic period, and with levels in the first quarter of 2024 almost triple those of 2019, and the increasing unreliability of services, are elements that favor the pushes to redesign supply chains. In fact, over the past three years, the solutions that multinational companies have tried to adopt to prevent the marginality of their global-scale operations from being completely eroded by the costs of containerized shipping have been the most varied and have involved organizational, technological, and supporting aspects of the development of new forms of competition in the maritime sector. These factors have included, for example:

- updating supplier and sub-supplier risk mapping, leading to the creation of true tower controls and reinforcing strategies that in the U.S. have been termed "China plus one", along the lines of what Apple chose in early 2022 to diversify the risk of supply disruptions from China by turning to suppliers in India and Vietnam;
- the restructuring of supply chains, seeking to bring suppliers closer together, with reshoring and friendshoring phenomena where possible, as developed by Ikea or Benetton in the furniture and clothing sector that have benefited the Mediterranean area at the expense of the Far East;
- the increase in safety stock, with pushes for growth in the real estate logistics market dedicated to warehousing.

These phenomena could be reinforced by European industrial policy choices aimed at encouraging reshoring in certain sectors, which are the subject of specific regulatory developments, technological and organizational innovations. These drivers of change, for example, will fundamentally alter global value chains in the automotive sector, one of the most exposed to the increased role of automation and digitization, and strategies aimed at:

- risk reduction through policies to reduce supply complexity, particularly on critical supplies such as electric chips and batteries on which EU-wide industrial policy has focused, in the wake of what the US has been promoting, and which will facilitate geographic proximity of suppliers;
- restructuring of production and logistics chains for cars and major components as a result of the acceleration toward an EU-wide decarbonization process that favors electric-powered cars over endothermic cars, banned from 2035, an earlier date than the rest of the world;

- accounting for the effects resulting from foreseeable protectionist measures in the European market due to the Carbon Border Adjustment Mechanism (CBAM) and Open Strategic Autonomy (OSA), envisioned by European sustainability policies and currently being negotiated for implementation aspects that will result in forms of "environmental duties";
- reduced sales due to higher prices, longer car life cycles, resulting in the development of new distribution and marketing models that are more sophisticated for both new and used cars and more regionalized in view of the increased focus on electrified cars at the EU level.

The Crisis of Transalpine Transport Networks

The vulnerability of the transportation network between Italy and the rest of Europe emerged dramatically during 2023, when a sequence of train accidents, landslides, and structural failures in settings just outside national borders threw into crisis major routes-in this case, transalpine routes of great economic interest to Italy.

These disruptive events come on top of routine and extraordinary maintenance and construction activities that, particularly in the rail sector, generate capacity shortages, detour and operational limitations in freight traffic on some of the main North-South axes between Italy and Germany via Switzerland.

The derailment of 30 freight train cars on the Swiss Gotthard line on 10 August 2023 forced the closure of one of the two tubes of the base tunnel, affecting the only route where as much as 75% of international transit freight volumes use rail (2022 figure compared to 69% in 1999) and only 25% use road. On the routes to France and Austria, rail's modal share is only 7% and 27% respectively, moreover down from 26% and 32% in 1999.

The halving of the capacity of the longest transalpine base tunnel (56.5 km) has forced a radical overhaul of the passenger and freight train schedule on Europe's busiest freight train axis, leaving less than 100 tracks per day available for freight compared to the standard 192, as well as requiring the detour of all passenger trains on the historic line, with time extensions and cancellations.

The absence of any indication of a reopening date, which is not likely until the end of 2024, is due both to uncertainties about the time frame for repairing the as many as 8 km of damaged track and to the difficulty of managing an extraordinary maintenance site for the first time in a particularly complex environment in terms of temperature and humidity.

Disruptions on the Frejus axis between Italy and France also severely affected interchanges due to a large landslide that caused a temporary closure of the highway and rail access to the tunnels on the French side from 27 August 2023. The event forced detours and long truck queues along the main alternative, the Mont Blanc route. Within a few weeks, it was possible to reopen the highway that had been opened in 1980. In contrast, the railway line, whose main technical features are firm at its inauguration, i.e., 1871, requires more complex rehabilitation works with assumptions of reopening only at the end of 2024, resulting in the cancellation of all trains, including the high-speed between Milan and Paris.

Further cause for concern emerged in early September when a structural crack was detected on the Gotthard Road tunnel (16.5 km, opened in 1980) that required a six-day total closure for urgent work.

Rounding out the picture that makes international economic relations critical to the national manufacturing and distribution system more costly and more uncertain are the unilateral restrictions imposed by the Austrian region of Tyrol with environmental justifications along the Brenner Road route. In this case it is a mix of restrictions by time slots, by types of truck engines and by sectoral type, with greater penalties for traffic segments involving heavier freight. These measures are hotly contested for their distorting and penalizing effects on Italian and German hauliers because the restrictions do not apply for Austrian operators. The European Court of Justice will be asked to rule on the basis of appeals brought by the main Italian trade associations.

In this context of total uncertainty, the Intergovernmental Conference between Italy and France decided to postpone part of the extraordinary maintenance activities of the Mont Blanc Tunnel planned for 2023 and 2024, prioritizing only the most urgent work on the 11.6-kilometer road tunnel inaugurated in 1965. Maintenance that will be recurrent for more than a decade, resulting in temporary closures to manage the complex construction site. Retracing the strategies developed at Gotthard and Frejus with the construction of the second road tube appears to be the strategic solution to overcome restrictions due to assumptions of prolonged closures.

The very limited number of road and rail options to gain access to continental Europe, the technical obsolescence of some of the main civil engineering artifacts, the over-reliance on road transport, i.e., the least environmentally, socially and economically sustainable mode of transport, as well as the overall fragility of the networks in the Alpine area with respect to climate change evolutions, which make landslides and floods more frequent, are very critical elements in themselves. In addition, the governance framework of transalpine transport policies is multilevel (European, bilateral and multilateral with Switzerland, national and regional), making it even more complex to find commonality toward rapid infrastructural, technological and organizational solutions that avoid uncertainties and extra costs for trade and tourism interchanges.

In fact, the penalties for Italy are obvious, as they impact the main routes to Italy's two countries with the largest trade and tourism interchange, such as Germany and France. If Switzerland is also included, these are the nations to which 27.4% of exports are destined, 24.1% of imports come from, and collectively generate a trade balance for the national economy worth €8.2 billion in the first half of 2023 alone. The economy of the country system (import and export of goods, but also tourism and social and cultural relations) is increasingly dependent on the efficiency of transalpine transport networks, so any effort to improve efficiency and pursue quick solutions to problems generates economic benefits that over the past few years have been increasingly evident, as the value of road and rail interchanges across the Alps in 2022 was €668.2 billion (source Bank of Italy, +148% in real terms compared to 2000).

The most important infrastructure solutions shared between the states, that is, the completion of the two rail projects considered priorities at the European level so much so as to obtain EU co-financing of 50% of the costs, that of the new line between Turin and Lyon and between Verona and Munich, will still require a little less than a decade of construction. Until 2032, the tools to mitigate the risks and damages due to the extra costs for interchanges can only be technological and organizational to encourage, for example, the optimization of railway train paths with functional specializations or revise tolls with rewards for the most efficient vehicles also from the energy point of view that can accelerate fleet renewals and encourage the use of the most sustainable fuels. The minimal goal also includes coordinating between the states road and rail yards, which are necessary for the now continuous extraordinary maintenance, and encouraging the development of intermodal transport, with specific attention to terminals, also in order to avoid the excessive concentration of flows and promote the resilience of a system that is clearly too fragile.

The Growing Role of Sustainability Issues and EU Policies in the Freight Transport Sector

Sector scenarios are not only conditioned by geopolitical crises or infrastructure limitations as previously described, but also by virtuous moves toward sustainability promoted by increasingly pervasive European policy initiatives. In fact, as remarked in the strategies of the “Fit for 55”[1] package and the Strategic Foresight report, EU initiatives and funds promote the following strategies of particular relevance to the development of intermodality in the freight sector, with the objectives of fostering efficiency and sustainability:

- increasing market areas for rail and short sea shipping over more polluting modes of transport, such as all-road;
- renewal of EU rolling stock and maritime fleets to improve their energy efficiency;
- development of the EU’s highly advanced production and technological capabilities.

The European Commission’s policy-making activities for the development of low-emission and energy-efficient freight transport take a systemic approach, as highlighted in the Commission’s communication on the Strategy for Sustainable and Intelligent Mobility.[2] The proposed strategies aim to double rail freight traffic and increase waterborne traffic by 50% and short sea shipping by 50%.

To further strengthen the ambitions of the European initiatives, on 11 July 2023, the European Commission published the “Greening Freight Transport” package of measures, which aims to help achieve the goal of reducing emissions in the transport sector by 90% by 2050 while supporting the economic growth of companies that adopt new, more efficient and sustainable freight transport policies. The package consists of three proposals,[3] among which the

[1] The “Ready for 55 %” package, unveiled by the European Commission on July 14, 2021, aims to align the EU climate and energy policy framework with the new economy-wide climate target for 2030 to reduce net greenhouse gas emissions by at least 55 % compared to 1990 levels and to put the EU on track to achieve climate neutrality by 2050.

[2] COM (2020) 789 final “A strategy for sustainable and smart mobility: putting European transport on track for the future”.

[3] COM (2023) 441/2 of 11 July 2023, “Proposal for Regulation of the European parliament and Of the Council on the accounting of greenhouse gas emissions

one of greatest interest for understanding scenarios in the international freight transport sector is on the proposed Regulation to establish a unified European framework for calculating emissions from freight transport operations, which uses the ISO 14083 standard as a reference for calculation.[4] This proposal aims to establish a uniform and internationally recognized measurement framework. Underlying the proposal is the idea that accounting for greenhouse gas emissions can lead customers to make more informed choices and influence the business decisions of those who organize and provide such services in the marketplace. The availability of reliable emissions data can encourage sustainability, innovation, and behavioral change toward sustainable transportation options.

On 7 November 2023, the European Commission presented a new proposal amending Council Directive 92/106/EEC regarding a support framework for intermodal freight transport and Regulation (EU) 2020/1056 for calculating external cost savings and generating aggregate data.[5] The overall objective of the directive is to facilitate the increase of intermodal transport in total freight transport within the EU, to reduce the external costs and energy consumption of freight transport. Alongside the obligations for the public sector, the proposal suggests introducing a requirement for eFTI (Electronic freight

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of transport services", COM (2023)/445, Proposal for a Directive of the European Parliament and of the Council amending Council Directive 96/53/EC laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic, and COM(2023) 443 final on issues of encouraging the use of rail for freight.

[4] The standard "Greenhouse gases - Quantification and reporting of greenhouse gas emissions from transport chain operations" was published in March 2023 by the International Organization of Standardization.

[5] EU Regulation EU 2020/1056 establishing a harmonized legal and technical framework for electronic communication of regulatory information (as defined in specific legislation, including control and audit information) between relevant economic operators and competent authorities in relation to the transport of goods in the territory of the European Union.

transport information[6]) platforms to provide functionality for calculating external cost savings and generating aggregate data on annual combined transport volumes. Full implementation will be made possible by the full acceptability of the eFTI platform expected to be mandatory from December 2025. The aim is to prepare a comprehensive analytical framework for the introduction of the cap-and-trade mechanism of the Emission Trading Scheme in the trucking sector as well. The proposal includes provisions for:

- Refocus support on operations that reduce negative externalities by at least 40% compared to road-only operations between the same departure and arrival points;
- Introduce an EU-wide exemption from temporary driving bans for short road legs of combined transport, ensuring better utilization of terminal capacity and non-road infrastructure;
- Set a competitiveness target for member states to reduce the average door-to-door cost of combined transport operations by at least 10% within 7 years;
- Oblige member states to adopt national policy frameworks to facilitate the adoption of intermodal transport;
- Create a transparency requirement for both intermodal transshipment terminals and national governments to ensure better customer access to information on the availability of services and facilities, as well as national support measures.

[6] The final text of Regulation (EU) 2023/957 of the European Parliament and of the Council amending Regulation (EU) 2015/757 to provide for the inclusion of maritime transport activities in the EU Emissions Trading Scheme and the monitoring, reporting and verification of emissions of additional greenhouse gases and emissions from additional types of ships was published in the European Official Journal on 10 May 2023.

These objectives are also reinforced by specific sectoral interventions, such as those related to the inclusion of maritime transport among the sectors to which the Emission Trading Scheme[7] applies at the European level, and by the target objectives of the FuelEu Maritime Directives[8] and the Alternative Fuel Infrastructure Regulation,[9] which will involve a change in the energy supply chains of commercial ships.

These aspects will be even more relevant in view of the fact that as of 1 January 2025, the Mediterranean will be a SECA – Sulphur Emission Control Area, i.e., an environment in which the maximum level of sulphur percentage in marine bunker must be less than 0.1%, compared to the very low sulphur oil standard of 0.5%. This regulatory requirement translates into higher costs for shipowners, who will therefore be incentivized to take faster and more cross-cutting action on energy efficiency mechanisms as the economic benefits will be even greater.

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[7] See Proposal for Regulation 562 (2021) of 14 July 2021 on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC updated on the basis of the Provisional Agreement resulting from Interinstitutional negotiations of 26 April 2023: Proposal for a regulation of the European parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC (COM(2021)0562 - C9-0333/2021 - 2021/0210(COD)).

[8] See Proposed Regulation 559 (2021) on the establishment of an alternative fuels infrastructure, repealing Directive 2014/94/EU of the European Parliament and of the Council, which was finally approved on 25 July 2023 and which requires that at least 90% of container and cruise ships calling at ports in the core network of the TEN-T program have the option of being supplied by electric charging infrastructure (cold ironing).

[9] See Proposed Regulation 559 (2021) on the establishment of an alternative fuels infrastructure, repealing Directive 2014/94/EU of the European Parliament and of the Council, which was finally approved on 25 July 2023 and requires that at least 90% of container and cruise ships stopping at ports in the core network of the TEN-T program have the option of being supplied by electric charging infrastructure (cold ironing).

The Need to Develop Strategies for Resilience and Sustainability

The succinct considerations regarding the international transport crises affecting the maritime and transalpine spheres and the urgencies in responding to the needs to decarbonize the sector are pushing operators toward a mix of articulated and complex organizational, commercial and technological solutions, using four main strategic levers:

1. rationalization of supplier choices and distribution modes so as to mitigate risks and reduce the distances to be traveled;
2. choice of the most efficient transportation mode and route in door-to-door logic, making use of advanced routing systems;
3. identification of ways to make the means of transport used more efficient, including through collaborative supply chain forms for the purpose of seeking economies of scale and better filling ratios, so that the certified carbon footprint can be mitigated;
4. enhancement of energy carriers with lower environmental impact, when available.

The process toward resilience and sustainability, which is strongly encouraged by the international and European regulations described above, is fostered by a growing awareness of the additional costs of inefficiencies. The additional costs are both operational, with immediate effects on corporate balance sheets, and environmental, with immediate costs to society as a whole, but which increasingly will affect balance sheets, especially in Europe where regulations are directed by the "polluter pays" principle.

3. Maritime Logistics: The Foundation of the International Economy Under Stress

Hercules Haralambides

Twenty-five years ago, in a MEL Editorial,[1] I coined the term "maritime logistics". That was the time when the maritime industry was viewed as a segmented collection of loosely related sectors like seaborne transport, ports, inland distribution, and everything else in between (banking, insurance, customs, etc.). In academia too, there were journals about shipping, or rail transport, or transport planning and more. A holistic approach to processes, all the way from the production of a shirt in Vietnam to its right place on the shelf at a Paris boutique, was missing. The need for an *integrated supply chain approach* was not felt; why should it? Actually, outside the military, the word "logistics" was not even fully understood, sometimes confused with other things.[2]

By a stroke of good luck, however, this was also the time when information and communications technologies (ICT) were entering the bigger picture, changing our lives forever. Nostalgically, I cannot help remembering dial-up connections to the internet; searching the net with 20 different search engines, or trying to understand what on earth that thing they

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[1] *Maritime Economics and Logistics* (quarterly), Palgrave Macmillan Springer.

[2] In Greece, for instance, the word was confused with "accounting" (λογιστική- sounds like "logistiki").

were calling Google was.[3] And at this juncture of my narrative I crave to say what I failed to say 30 years ago, when the internet was taking over our lives: we are lucky today to be unable to even imagine where *generative artificial intelligence* will have taken us 30 years from now. According to Elon Musk, by the end of 2026, AI will be smarter than the smartest person on earth.

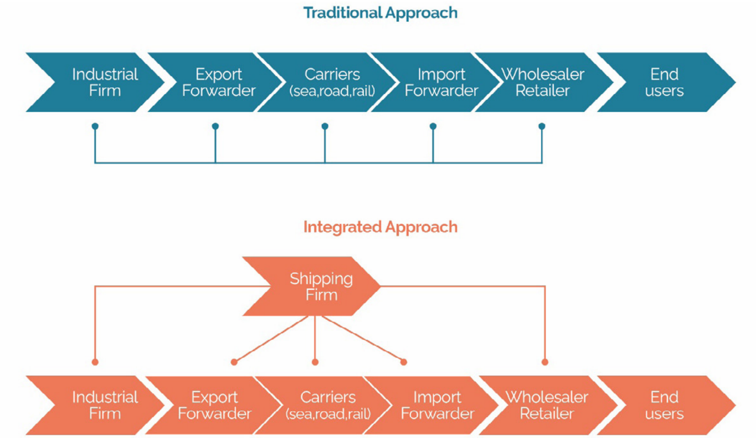
One of the effects of ICT was to help us realize the benefits of integration; in other words, the gains to be had from logistics and supply chain management, thanks to the elimination of *transaction costs*. Among the first to seize this opportunity were ocean container carriers (Figure 3.1): global multi-billion enterprises like Mediterranean Shipping Company, Maersk Line, Cosco, CMA CGM and Hapag Lloyd. Their thinking was clear: port-to-port transportation had become *homogenized*; carriers had more or less the same ships and technology and, for their client, the shipper (cargo-owner), it made little difference if his[4] container reached Europe on a Cosco or a Hapag Lloyd ship. Carrier competition was thus excruciating, squeezing margins and increasing the business risk from owning hard assets like ships, in a cyclical industry.[5] Carriers were therefore realizing that survival meant two things: either they collude, rather than compete, or they differentiate their services, targeting individual exporters; or both.

[3] Not to mention submitting research papers in hardcopy and communicating by fax!

[4] References to the masculine include the feminine.

[5] The shipbuilding cost of a modern containership currently exceeds €100 million.

Fig. 3.1 - From traditional to integrated approach in shipping



Source: H. Haralambides, "Gigantism in container shipping, ports and global logistics: a time-lapse into the future", *Maritime Economics & Logistics*, vol. 21, no. 1, pp. 1-60.

In the seaborne transportation of containers, collusion means two things: price-setting liner *conferences* (banned from European trade in 2008 but existing in the rest of the world), and cost-minimizing *global shipping alliances* (GSA), also to be banned from Europe in 2025. These two forms of carrier cooperation, as I discuss below, go a long way towards explaining – admittedly only partly – the "stress" on maritime supply chains that is the focus of this chapter.

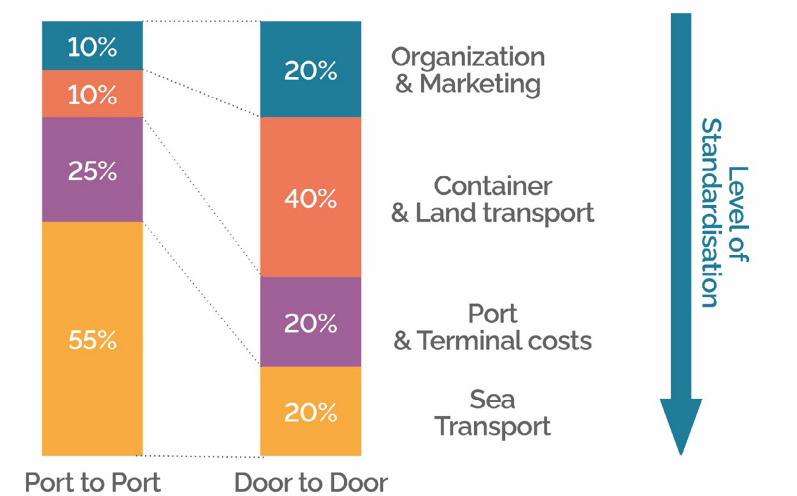
Targeting individual shippers by offering them tailor-made door-to-door solutions[6] required a very different business model. Now, instead of relying on freight forwarders to fill their ships (something I have called "wholesale shipping"), carriers had to develop an extensive sales network of thousands

[6] The "shirt" example I used above was not just hypothetical. In my years at NOL/APL in Singapore, we were advising stakeholders from the production line in Vietnam, all the way to the height of the shelf the shirt should be placed on, in a New York boutique.

of employees around the world who would talk to shippers regularly in an effort to win their business (I have termed this "retail shipping"). Some shippers were responsive; mostly the bigger ones with a need for sophisticated solutions. Others required just port-to-port pricing, thinking that it would be better if they organized the various supply chain components (e.g., hinterland transport) themselves.

The two business models have a different cost structure (Figure 3.2): in the wholesale model, the largest share of total costs is attributable to ocean transportation (55%). In the retail model, by contrast, the largest share of total costs (in addition to manpower of course) is attributable to container management, land transport, warehousing and distribution.

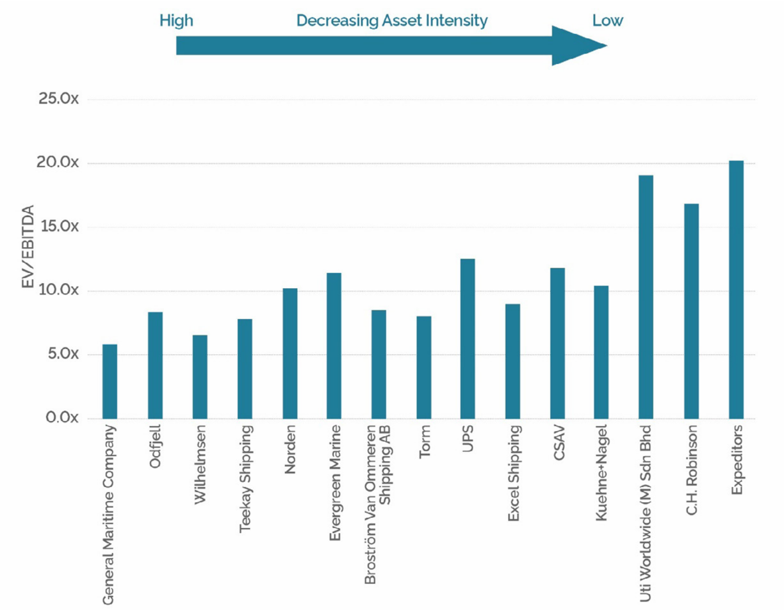
Fig. 3.2 - Wholesale-Retail shipping: from a standardized commodity (port-to-port) to a tailor-made service (door-to-door)



Stepping into door-to-door transport, carriers came into direct competition with logistics service providers, also known as third-party logistics service providers (3PLs), and NVOCCs (non-vessel owning common carriers). The interesting thing is that these companies are both competitors *and* clients of carriers. 3PLs include the likes of DHL, FedEx, UPS, Kuehne + Nagel, and many others. Many of them started as conventional post offices, before building on their expertise, from the local distribution of letters to the global distribution of big parcels and finally containers. Their global logistics operations may require hundreds of thousands of container-ship slots (TEUs), which they must buy from carriers. They thus become clients of carriers, while at the same time competing with them.

An NVOCC, as the name suggests, is a virtual carrier; i.e., one who operates as a (common) carrier albeit without ships. 3PLs can be NVOCCs, as can large freight forwarders. The model here is simple: instead of owning shipping capacity, along with the risks that this entails, NVOCCs just rent from the carrier as much capacity as they require each year. Knowing fairly accurately their short-term demand for ship capacity, NVOCCs thus "ride the cycle", rather than sink with it, as carriers do when things do not go well. By reducing their market risk in this way, NVOCCs improve their financial results. In Figure 3.3, we can see that logistics companies tend to be valued higher than pure transportation companies. By being *asset-light*, thus able to "ride" the business cycle, they have always performed better financially during economic downturns and recessions. Moreover, due to their broader diversification, logistics revenues are more stable over time. The model is not much different from the *Make-to-Order* model of up-scale car manufacturers, whereby production does not start until a "batch" of, say, 1000 car orders comes in from their dealers.

Fig. 3.3 - Financial performance of transport vs logistics companies



Source: Bloomberg

An interesting question arises at this point. Why do carriers sell capacity to their competitors? Why do they give away their comparative advantage, i.e., the ownership of vessels, when they themselves are trying to enter the logistics market? Is this not like giving your enemy the knife to stab you in the back? I have been debating this question with carriers for years.[7] Their answers do not vary much, but let me describe this discourse in the form of a rather entertaining dialogue:

- Why do you sell capacity to the logistics guys?
- They are big customers who help me fill the ship.
- But if you cannot fill it yourself, together with your alliance partners, why do you build big?

[7] Google my articles in Lloyd's List.

- To have economies of scale.
- But you can only have economies of scale, and thus improve competitiveness, if you can fill the ship!

And somewhere here the discourse always stops.

Eventually, carriers saw the light: better coordination with alliance partners would be the way forward, both in building bigger ships *and* for utilizing them better. Alliances thus became the mainstay of the industry, particularly after the abolition of liner conferences from European trade in 2008.[8]

As I said above, the two forms of cooperation in liner shipping, conferences and alliances, can help us explain "stress" in supply chains or, better, the lack of the necessary "slack", or "redundancy", or "excess capacity". *Stress* can be caused either by our operating model (e.g., alliance agreements on ship-bay sharing, cf. below), or by unforeseen external events (e.g., Covid-19). In a number of my earlier publications,[9] I have tried to show *slack* as an important operating cost – rather than as evidence of inefficiency, which is the usual way of looking at it by the layman – aimed at "absorbing" the effects of stress. Ports and container terminals give us an excellent example of this: through many studies on the issue of congestion, we have established that when a port (or terminal) exceeds 75% of capacity utilization, congestion starts to set in, and this is unacceptable to today's carriers, who have no hesitation in switching ports and moving their business to nearby competitors. It is worth remembering that containers are "footloose" and relatively unconstrained by *sunk costs* or loyalties to a specific port. Building and maintaining excess

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[8] H. Ju, Q. Zeng, H. Haralambides, and Y. Li, "An investigation into the forces shaping the evolution of global shipping alliances", *Maritime Policy & Management*, 2023; H. Ju, Q. Zeng, and H. Haralambides, "Consequences of freight rate volatility in liner shipping and the role of strategic alliances", *Ocean & Coastal Management*, vol. 252, 2024.

[9] Cf. P. Kent and H. Haralambides, "A perfect storm or an imperfect supply chain? The U.S. supply chain crisis", *Maritime Economics & Logistics*, 2022.

capacity in ports is therefore a necessity and a cost, although this is often difficult to explain to public and private financiers of port infrastructure.

A similar logic applied (and applies) to liner conferences: as price-setting cartels, conferences were in a position to enforce tariffs that covered the costs of *all* their members, even the most inefficient ones. Excess capacity was thus built into their port rotations, filling ships was less important, and prices were stable to the extent they were even published in conference tariff books. Growing the business was easy and their market expectations were *adaptive*:[10] in other words, pricing was a "steady as she goes" decision which extrapolated the past into the future.

The situation in aviation, before our "open skies" policies, was not much different and this is another good example of imperfect competition, whereby an aviation cartel (IATA) would build-in excess capacity. *Legacy* carriers (national champions like Pan Am, TWA, Sabena, Varig, etc.), many of which are now defunct, would offer sufficient capacity at stable prices, known months in advance. In contrast, if you try to book a flight on the internet nowadays, the price may change twice before you complete the transaction and this is extremely frustrating. This is called "yield management": a difficult mathematical optimization, addressed in countless PhDs we have supervised, but an absurdity nonetheless, highlighting the downside of too much *marginal cost-based* competition and the potential benefits to be gained from concentrating decision-making, by looking instead at long-run average costs.[11]

With alliances, however, the "deal" and its effects are very different. Here, the emphasis is not on revenue maximization

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[10] M. Fusillo and H. Haralambides, "Do carrier expectations indicate industry structure in container shipping? An econometric analysis", *Journal of Shipping and Trade*, 2020.

[11] The counter-argument on building-in excess capacity is that this increases *sunk costs*, thus deterring aspiring newcomers, strengthening the monopoly position of incumbents (S. Martin, *Advanced Industrial Economics*, Blackwell, 1993).

(as in conference price-setting) but on cost minimization. And this is where the problem starts, for daily business has taught us that there is no end to the exercise of minimizing costs; an exercise often exceeding the limits of ridiculousness. In alliances, cost minimization entails sharing capacity, jointly planning itineraries and deciding on the types of ships to be deployed, or even sharing capacity (bays) on a single ship.[12] It thus becomes obvious that cost minimization allows no "slack". We saw the result of this during the Covid-19 pandemic, with blank sailings, big call sizes, irregularity, unreliability; missing, misplaced, and abandoned containers; complaining shippers, and regulatory intervention:[13] *in short, we have had a ghastly mess*.[14]

However, the more fine-tuned a system (or network) is, and the more sophisticated its optimization, the more profound are the effects and ramifications of a disruption when it happens, in the absence of slack. The stress on supply chains in such cases is sizable. The Netherlands, for instance, boasts a road network that ranks among the best in the world in terms of

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[12] A nightmare for berth operations, when giant Ship-to-Shore cranes must limit their movement to specific bays (H. Haralambides, "Gigantism in container shipping, ports and global logistics: a time-lapse into the future", *Maritime Economics & Logistics*, vol. 21, no. 1, 2019, pp. 1-60.

[13] The words of an "angry" President Biden, responding to complaints of US exporters, who were unable to find empty containers during the Covid-19 years, or sometimes waiting for weeks at Los Angeles to take delivery of their import container, show a clear understanding of the situation: [...nine major shipping companies consolidated into three alliances control the vast majority of ocean shipping in the world and each of these nine are foreign-owned. During the pandemic, these carriers increased their prices by as much as 1000% while families and businesses struggled around the world. These carriers made 190 billion dollars in profit in 2021, 7 times higher than the year before and they raked in the profits, and the costs get passed on, as you might guess, directly to consumers, sticking it to American families and businesses. These foreign-owned carriers have also been refusing to carry American-made products back to Asia…].

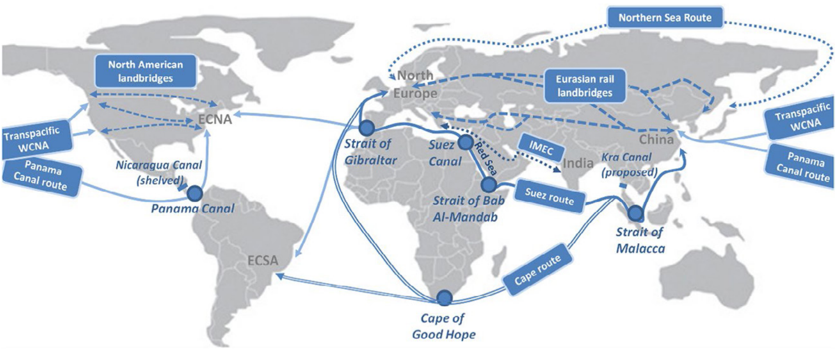
[14] Expression borrowed from the cinematographic masterpiece of Walt Disney, *Marry Poppins*: [...A British bank is run with precision. A British home requires nothing less. Tradition, discipline, and rules must be the tools; without them: disorder, catastrophe, anarchy, *in short, you have a ghastly mess*...].

quality and sophistication. As long as things go well, the flow of traffic is smooth, even during morning peak periods. The minute a serious accident happens somewhere, however, the whole country can come to a standstill, with tens of thousands of kilometers of queues. If frequent, such disruptions have other, more serious, ramifications too. As highlighted above, logistics optimization (together with containerization) not only changed traffic, transport and trade, it also changed our lives and the way we go about our daily activities. The prerequisite for this has a name: “reliability”. When, for example, I go to the airport, I know, to the minute, what time I must leave home. If, however, taxis are on strike, trains do not run, etc., I need to leave home one hour earlier; this is my own “inventory cost”, and it is indeed a cost!

Stress on supply chains is not caused only by unreliability and the ensuing higher inventory costs, but also by external, unforeseen, and unanticipated shocks, such as Covid-19, as discussed above. Generalizing, any obstacle or hindrance to the smooth flow of trade imposes stresses on fine-tuned supply chains. Such hindrances can be what I call “chokepoints”. Below, I discuss some representative examples, together with the “safety valves”, that may or may not be at our disposal to bypass them. Figure 3.4 shows the three chokepoints I will discuss, together with their (possible) bypasses; the latter motivated by concerns about the security of navigation and of naval deployments.[15] Of the many such bottlenecks to trade, I consider the following three to be the most important (their bypasses are shown in brackets): Suez Canal (Cape route; northern sea route; IMEC [India-Middle East-Europe-Economic Corridor]; Eurasian rail land bridge); Panama Canal (Suez Canal; North American land bridge; Nicaragua Canal [shelved]; PILA [Puerto Internacional Las Americas], Colombia); and the Malacca Strait (Kra Canal, Thailand; and Sunda Strait, Indonesia).

[15] H. Haralambides and O. Merk, “The Belt and Road Initiative: Impacts on Global Maritime trade flows”, International Transport Forum Discussion Papers, No. 2020/02, OECD Publishing, Paris, 2020.

FIG. 3.4 - CHOKEPOINTS AND INTERNATIONAL TRADE FLOWS



Source: Notteboom et al (2024)

The Suez Canal

At the time of writing, the Bab al-Mandab Strait, this most crucial chokepoint of international trade, is making headlines due to the Houthi militia attacks on commercial shipping, as a *quid pro quo* for the Israeli attacks on Gaza. The roots of the civil war in Yemen are far too complex to be analyzed here, and go beyond the scope of this article anyway. However, it might not be entirely wrong to suggest that this conflict – which has claimed the lives of over a quarter of a million people due to the hostilities and their consequences – is a theater of Saudi-Iranian rivalries. With the accession of the two countries to the BRICS (effective 1 January 2024), the world had hoped that a kind of *rapprochement* between the two arch-rivals was on the horizon, brokered by China, Saudi Arabia's biggest oil buyer. Unfortunately, at the January 2024 Davos meeting in Switzerland, Saudi Arabia announced that "*Saudi Arabia has not yet joined BRICS*".[16] Apparently, the country's indecision is not totally unconnected with either the

[16] "Saudi Arabia has not yet joined BRICs – Saudi Minister, Davos meeting", *Reuters*, 16 January 2024.

evolution of the Gaza/Red Sea situation, or the renewed friction between China and the US, in spite of the warm encounter of the two leaders, Joe Biden and Xi Jinping, at the San Francisco APEC meeting in November 2023.

But this is not the first time the Canal has choked trade since its inauguration in November 1869, at a grand international event, frequented by royals and dignitaries from around the world, immersed in the divine sounds of Verdi's Aida. The canal has since closed three times, in 1956 (the Suez Crisis), 1967 (the Six-Day War) and 1973 (the Yom Kippur war), and whenever there were concerns about the security of navigation and naval deployments.[17]

The Bab al-Mandab Strait, the southern entrance to the Red Sea in the Gulf of Aden (Figure 3.4), is the Cerberus[18] that guards the entrance to Europe for Persian Gulf oil and Asian manufactures. Shared by Yemen, Eritrea and Djibouti, the strait has a width of approximately 30 km, divided into two channels by Perim Island.[19] The strait makes the strategic importance of the Gulf of Aden even more important. The Gulf has traditionally been plagued by high levels of piracy, smuggling, and illegal arms trafficking. International cooperation initiatives and regional laws have had only limited success in improving the security situation in the Gulf, where many major powers, including China (in Djibouti) and the US, maintain a military presence.

Recently (March 2021), another event, this time commercial, blocked the canal for six days, wreaking havoc on international trade. Hundreds of ships were stranded at the two ends of the canal, disrupting supply chains and increasing inventory costs by billions of euros each day. The event in question was the running aground of Evergreen's mega-ship "Ever Given", one of the biggest container ships in the world at the time.[20]

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[17] Haralambides and Merk (2020).

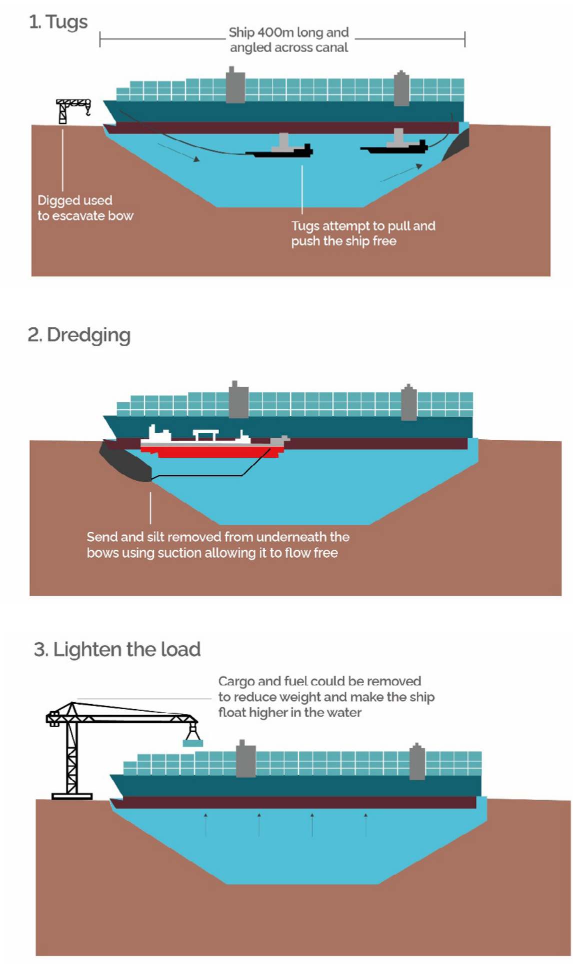
[18] The ferocious three-headed dog that guarded the entrance to the underworld (Hades), according to Greek mythology.

[19] H. Al-Yadomi, *The strategic importance of the Bab al-Mandab Strait*, US Army War College, Pennsylvania, 9 April 1991.

[20] 20,124 TEU.

The 400-meter giant got wedged sideways in the 265-meter-wide canal, and the mission to dislodge and refloat it required unprecedented international efforts, including dredging, towing, and (partly) lightering (Figure 3.5).

Fig. 3.5 - Dislodging and refloating the Ever Given container ship



The Suez Canal serves 12% to 15% of international trade, being the principal artery of the Europe-Asia cargo flows. It is estimated that, on average, 50 ships transit the infamous waterway every day. Alternatives (bypasses) do exist, however (Figure 3.4), albeit at higher costs, longer distances and higher environmental impacts. These alternatives are discussed below.

Circumnavigating Africa: The Cape Route

The first, but by no means new, alternative to the Suez is the circumnavigation of Africa, known as the "Cape Route" (sailing around the Cape of Good Hope). The route adds approximately 4,500 nautical miles (or 8,000 kilometers) to the distance between Shanghai and Rotterdam and, depending on sailing speeds, 12 more days in sailing time, assuming an average speed of 16 knots.[21] To maintain weekly schedules, this would require two extra ships per loop, or about 200 ships in total.

South European ports are affected even more by the Cape route, as ships now have to approach these ports via the much longer distance through the Strait of Gibraltar (Figure 3.4). The impact of the crisis on the Med hubs of Piraeus, Genoa, Malta, Valencia etc., is graver than this though. The Med Basin, the Romans' *Mare Nostrum*, is what I have often called the "*hub of hubs*" and perhaps the most important sea stretch in the world, connecting four continents: the Middle East (Asia), Europe, Africa, and North America. Especially as regards the latter, Suez has been functioning in competition with the Panama Canal for the North American East Coast (ECNA) market, housing the richest consumption centers in the world. To put it simply, ships from Asia transiting the Suez Canal could trans ship in a Med hub and continue crossing the Atlantic to the ports of New York – New Jersey (NYNJ), Norfolk, Savannah, Charleston,

[21] T. Notteboom, H. Haralambides, and K. Cullinane, "The Red Sea Crisis: ramifications for vessel operations, shipping networks, and maritime supply chains", *Maritime Economics & Logistics*, vol. 26, 2024.

and Halifax (in Canada). This trade is now largely lost to the Atlantic ports of West Africa and Portugal.

In the present (2023-24) Red Sea crisis, the impact of diverting to the Cape Route on the running and voyage costs of ships, and consequently on freight rates too, is not difficult to comprehend: ITF (2024) has calculated an average cost increase of $272 per FEU for a median-sized container ship while, at the beginning of the crisis, freight rates increased by more than 200%, both to northern Europe and the Mediterranean. As an example, the Shanghai Containerized Freight Index (SCFI) for Northern Europe increased from $707/TEU in mid-November 2023 to $3,103/TEU in mid-January 2024. Mediterranean services saw similar price increases. I would be remiss not to mention *ad passim* here that such rate hikes (and related surcharges) cannot be easily justified by the above cost increases, leading one to again comment on the lack of adequate competition in container shipping.

With regard to the higher environmental costs of air emissions as a result of diverting to the Cape Route, these have been estimated at 42% for an individual vessel, and 67% for the fleet needed to operate a typical weekly service between Asia and Northern Europe.[22] This is a setback for the shipping industry's efforts to respect the International Maritime Organization (IMO) targets towards reaching "net-zero" by 2050.

The Northern Sea Route (NSR)

The Arctic Northern Sea Route (NSR), (Figure 3.4), is a niche alternative to the Suez, studied and tested over many years, by major companies such as Cosco and Maersk, as well as various academics. The route, connecting East Asia (Japan, China, Korea) to Northern Europe, is 40% shorter compared to the Suez route and, as a result of the accelerating melting of Arctic ice (due to global warming), it could potentially

[22] Ibid.

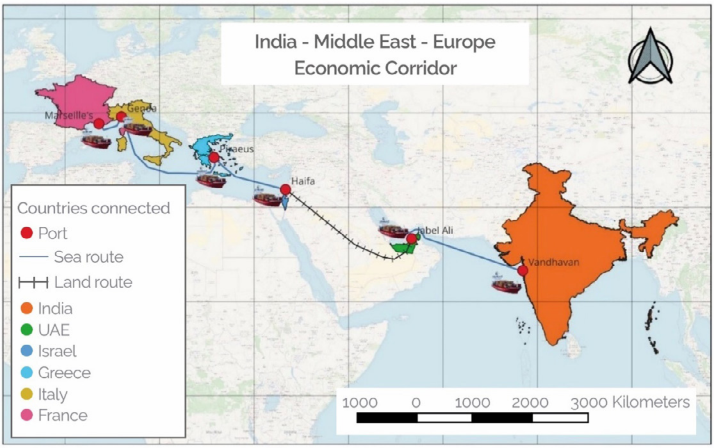
claim an increasing share of Suez traffic, in the bilateral trade between China and the European Union, which is rapidly approaching one trillion US dollars. As Figure 3.4 shows, the NSR runs along Russian territorial waters, with various, costly navigational control stations which, among other things, might raise legitimate maritime law questions on the freedom-of-navigation principle. In terms of trade benefits, the main beneficiaries are China and Russia, the former hungry for the rich resource endowments of the Arctic, comprising first and foremost its vast quantities of natural gas.

Reducing sailing distances has various advantages in terms of fuel consumption and atmospheric emissions. To a great extent, however, the benefits of the NSR are eroded by the high cost of ice-class vessels, slower speeds in ice navigation, use of Russian (nuclear) icebreakers, control station passage fees, etc. Moreover, ports along the way are not yet prepared for this trade and it will be years, if ever, until this new alternative to Suez presents itself as a serious contender in the Asia-Europe trade.

The India-Middle East-Europe Corridor (IMEC)

The idea of a new corridor, which would offer a routing alternative to Suez – and perhaps a potential "competitor" to China's Belt and Road Initiative (BRI) – was introduced by President Biden at the G20 summit in India (September 2023). The underlying objectives of IMEC are not much different to those of BRI and of multinational trade corridors in general: *to improve the economic, social and political integration of the countries involved, through regional development and better connectivity among their ports*. The $20 billion IMEC project would shorten distances by 40% *vis à vis* Suez, connecting India to Europe via a complex sea-rail multimodal corridor. Specifically (Figure 3.6), the west coast of India, starting from the newly licensed mega-port of Vandhavan (Figure 3.6) would connect by sea to Dubai. There, containers would be loaded onto trains traversing Saudi Arabia to reach the Israeli port of Haifa in the Eastern Mediterranean. The final leg of the corridor is again "maritime", bringing containers from Haifa to the south European ports of Piraeus, Genoa and Marseille and from there, by road and rail, to the rest of continental Europe. In addition to trade, the project envisions underwater cabling for the transmission of electricity, communications and internet.

FIG. 3.6 - THE INDIA-MIDDLE EAST-EUROPE CORRIDOR (IMEC)



Source: Khan et al (2024)

Detailed studies have not yet emerged, which reinforces criticisms that the whole thing is mere sensationalism. Indeed, according to some preliminary costings and timings that I have attempted, the number of transshipments that would be needed and the limited capacity of the rail leg are such that IMEC does not pose a serious threat to either Suez or BRI. As soon as IMEC was announced, the response of Turkey was instantaneous: "there can be no corridor that excludes Turkey". The reprisal did not take long to surface. In early 2024, Turkey presented its own "bypass" to Suez: starting from the Al-Faw

Grand Port,[23] at the Upper (Persian) Gulf, near Basra (Figure 3.7), a 1,200 km ($17 billion) multimodal corridor would traverse Iraq, all the way to the Turkish borders, branching out westwards to Europe.

Fig. 3.7 - The Al-Faw Turkey-Iraq multimodal corridor

Source: Splash247

Finally, in spite of India's obvious interest in the IMEC project, particularly as *others* are paying for it, the country has never relinquished its interest in Russia's International North South Transport Corridor (INSTC) which, starting from the Iranian Gulf port of Chabahar, continues north, over a distance of 7,000 km, eventually reaching Moscow, calling on its way at Tehran and Baku (Azerbaijan) and, from Moscow, branching out westwards to Turkey (for solutions offered by air transport as well as by the Eurasian rail network, the latter promoted strongly by China as the *Belt* part of its Belt and Road Initiative.[24]

[23] To be developed in a joint venture with AD Ports of Abu Dhabi.
[24] See Haralambides and Merk (2020) and Notteboom et al. (2024).

The Panama Canal

After the Suez, the Panama Canal is the second most important artery (and chokepoint) of international trade, connecting the Pacific to the Atlantic Ocean, thus feeding mainly the east coast of the Americas with Asian exports and, as of recently, supplying Asian markets with US natural gas and Latin American agricultural produce.

The construction of the canal took a good 10 years and thousands of workers died[25] from tropical diseases during the excavation works, both during the failed French efforts of Ferdinand de Lesseps (1881-94), and the subsequent US efforts of 1904-14. The canal was inaugurated on 15 August 1914.

A significant competitor of the Panama Canal, in supplying the East Coast of North America (ECNA) with Asian products, is the *US Land bridge* (Figure 3.4) and to a lesser extent the circumnavigation of the treacherous waters of Cape Horn – the southernmost tip of Latin America. As an alternative intermodal corridor, the land bridge was developed in parallel with the construction of *post panamax* ships (cf. below). To put it simply, Asian cargo is unloaded at the North American West Coast (WCNA) ports of Los Angeles, Long Beach, Oakland, Seattle, Tacoma and Vancouver (in Canada), and from there, containers are loaded onto railcars and road vehicles, travelling an average distance of 4,000 kilometers to the US Midwest (Chicago, Detroit) and then to ECNA.

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[25] To protect themselves from the scorching sun, workers wore white straw hats, finely woven in Ecuador: a centuries-old craft, proudly supplying the world today with the hallmark of elegance – the Panama Hat. The hat became famous when President Roosevelt wore it during his visit to Panama, to observe first hand progress with the excavation. And said the President: "...The credit belongs to the person who is actually in the arena, who strives valiantly, who errs and comes up short again and again, because there is no effort without error and shortcoming; who, at the best, knows in the end the triumph of high achievement and who, at the worst, if he fails, at least fails while daring greatly, so that his place shall never be with those cold and timid souls who know neither victory nor defeat...".

Recently (2023-24), the fresh-water Panama Canal has been suffering from low water levels, due to drought conditions (limited rainfall). This has deprived the canal of roughly one third of its traffic and, combined with the Red Sea crisis, has created the "perfect storm",[26] when it comes to supplying the ECNA. On the positive side, the new situation has strengthened the position of the WCNA ports – and, apparently, of the US Land bridge – which have been losing out consistently to the ECNA ports over the past few years.

For nearly 10 years, up to the late 1980s, the maximum size of container ships had remained unchanged at around 4,500 TEU. These ships have come to be known as *Panamax container ships* and, to many, they are the workhorses of the industry. The limiting factor to the growth in ship sizes, at the time, was the Canal itself, whose locks were 33.5 meters wide. This meant that a ship could not be wider than that, i.e., wider than 13 containers across the vessel's beam.[27]

In 1988, American President Lines[28] (APL) of Oakland, US, made the bold decision to introduce the C10 class of vessels with a beam (width) of 39.4 meters (14 or 15-across). These were the first *post-panamax* ships, for they could no longer transit the Canal. After this, the growth in container ship sizes has been unstoppable (Figure 3.8).

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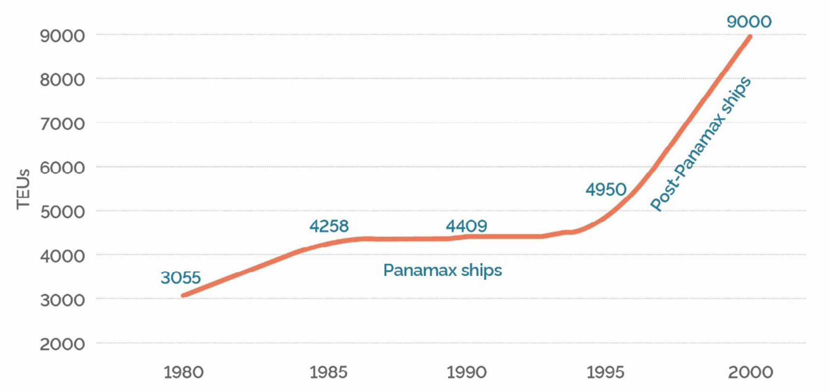
[26] Kent and Haralambides (2022).

[27] The width of a container is 2.5 meters. Thus, 13x2.5=32.5 meters, just allowing half a meter of clearance at each side of the Canal, to its own width of 33.5 meters.

[28] Bought by Neptune Orient Lines of Singapore, which was itself acquired recently by CMA CGM of France (all, members of the Ocean Alliance, together with Cosco, and Evergreen). I was lucky enough to experience from within the unparalleled operational efficiency of NOL/APL when, for seven years, we were running their *centralized management trainee program* in Singapore. These, together with my years of running the Italian port of Brindisi, are such enriching experiences that they become almost a prerequisite before one picks up the pen and starts to theorize on the fascinating world of *Maritime Economics & Logistics*.

Fig. 3.8 - Developments in Maximum Size of Container Ships



The thinking of APL (and all other carriers who followed them in the 1990s) was simple, as all solutions to complex problems must be:[29] the *economies of scale* of the largest, post-panamax, vessels; the money we save by not paying canal dues and fuel costs; and the time-savings we achieve thanks to the land bridge, should allow us to offer intermodal rates attractive enough to ECNA consignees (cargo-receivers), *vis à vis* those of the "all-sea route" (i.e., through the Panama Canal). Moreover, and as far as we are concerned, thought the management of APL, having a uniform size of vessels (no size limitations existed at the time in Suez transits) is a most valuable operational advantage, in terms of ship swaps and fleet scheduling.

The spectacular growth in ship sizes – approaching the 25,000 TEU landmark at the time of writing – obliged the canal to expand its capacity with a new set of locks, parallel to the old ones, at both entrances (oceans) to the canal, allowing passage to ships of "22-across" (or approx. 14,000 TEU). These are now known as the *Neo-Panamaxes*. The expansion cost Panama a good $6 billion. As to be expected, Egypt followed

[29] To quote Bill Gates, "if I want solutions to a complex problem, I give it to a lazy person; I can thus be sure he will find the simplest and quickest solution".

suit, now offering a two-way traffic in Suez at a massive cost of nearly $9 billion. Once again, interesting questions were raised as to whether the two canals compete or collude.[30]

In spite of the millions spent on research, on global trade forecasts and feasibility studies concerning the expansion of the canal, the capacity of the new locks was soon to be overtaken, presenting a new limitation to the newest generations of container ships, now built far bigger than 14,000 TEU. Did the Panama Canal Authority not see this coming? I believe they did, at least some friends on PCA's Advisory Board did, but there were two important parameters they had to take into account (other than costs, of course): i) the rocky seabed of the USEC, making dredging costs prohibitive, and ii) the (tidal) clearance under some bridges of the New York – New Jersey port system, which does not allow the latest generation of container ships to pass beneath them.

A Digression

It might be interesting to make a digression at this point, which some of my readers may find interesting or useful. Despite the continuous capacity increases of today's "giants",[31] it seems their dimensions have remained unaltered to what I have earlier called the *universal constant* of 400-60-16. That is, 400 LOA (length overall); 60 meters beam and 16 meters draft. Naval architects have optimized designs, turning ships into floating platforms, not limited by the usual V-shape of a ship's hull. Will we see a new universal constant any time soon? Probably. Starting with Rotterdam's RWG (Rotterdam World Gateway), major hub-ports are ordering the newest generation of Ship-to-Shore (StS) cranes with a boom[32] of 65 meters, designed to

[30] My own views hinge on the latter.

[31] Haralambides (2019).

[32] The horizontal arm of the crane (Figure 3.9) along which a trolley runs back and forth, landing containers on the terminal's apron or, directly, on a railcar,

serve ships of 26 rows or 30,000 TEU. This, if widespread, and widespread it will be, would certainly entice carriers to build ships of that size. A "chicken or egg" question arises again: does port technology adapt to ship sizes, or does it itself encourage the construction of larger ships? Over the years, my answer has been unswerving: the critical "variables" leading to gigantism in shipping are port technology, efficiency and productivity.[33] To put it simply, it is those advancements that minimize ship turnaround time and ship stay time in port.

And as one thing brings up another, I couldn't help but remark here that ports' haste to achieve technological prowess is driven by regional port competition; and often, not only in the port domain, competition breeds waste.[34] Recently, the new tendency in port policy, pioneered by China, is port *coopetition*: an area I have been working on for years with my Chinese (and other) colleagues.[35] In short, regional port infrastructure ought to be centrally planned, to avoid wasteful duplication of resources and situations whereby carriers play one port against the other. Subsequently, the private sector is invited, competitively and in competition, to develop and manage this infrastructure.[36]

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chassis, internal terminal truck, or AGV (Automatic Guided Vehicle).

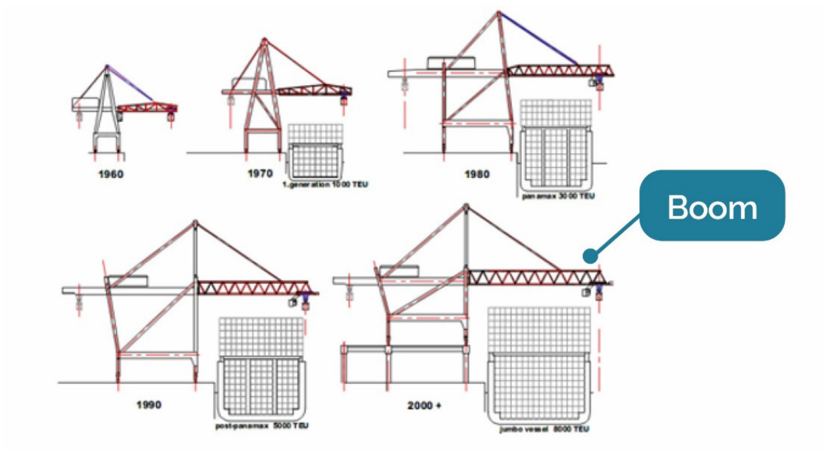
[33] Haralambides (2019).

[34] Not to be confused with *slack* capacity.

[35] Z.H. Munim and H. Haralambides, "Competition and cooperation in intermodal container transshipment: A network optimization approach", *Transportation Business & Management*, vol 26, 2018, pp. 87-99; S. Wan, L. Weixin Y. Ma, and H. Haralambides, "On determining the hinterlands of China's foreign trade container ports", *Journal of Transport Geography*, vol. 85, May 2020; C. Wang, H. Haralambides, and L. Zhang, "Sustainable port development: the role of Chinese seaports in the 21st century Maritime Silk Road", *Int. J. Shipping and Transport Logistics*, vol. 13, no. 1/2, 2021; Q. Ma, P. Jia, X. She, H.E. Haralambides, and H. Kuang, "Port Integration and Regional Economic Development: Lessons from China", *Transport Policy*, vol. 110, 2021, pp. 430-39; S. Li, H. Haralambides, and Q. Zeng, "Economic forces shaping the evolution of integrated port systems - The case of the container port system of China's Pearl River Delta", *Transportation Economics*, 2022.

[36] We did this in Italy too, in the years when I was running the port of Brindisi,

FIG. 3.9 - SHIP-TO-SHORE (QUAY CRANE) DEVELOPMENTS



The ratio of LOA to beam is fairly fixed and, in today's designs, ships become bigger by becoming wider rather than longer. Sausage-type ships are not possible for a number of reasons, including ship safety at sea: if raised on the crests of two waves, in a rough sea, a fully laden "sausage" can break in two like a cucumber. If this were not so and we were able to build larger ships by making them longer, while keeping their width constant, the cargo handling problem in port could be easily solved by adding an extra StS to the operation, so that it would still be possible to turn the ship around in the same time – currently, a couple of days. However, as soon as the ship becomes wider, e.g., 25 or 26 rows wide, *all* our StS cranes with a boom length of 60 meters or less become useless and need to be replaced with the new generation, costing well in

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and we reduced the number of port authorities from 24 to 15. My neighbor and competitor, the port of Bari, was just 100 km north and carriers – RoPax operators connecting Italy to Greece – did play one port against the other. Our response was to collude: to put it simply, if someone threatened to leave me to go to Bari my answer would be "*Don't let me keep you*". Once in Bari, however, the answer of my colleague there would be "*I am sorry but I have no available berth for you*" (and vice versa of course).

excess of $10 million each. Considering that a two-berth, 1 km quay-wall would normally need 10 of these cranes, the cost of replacement is substantial, particularly if it has to be done every seven to eight years, as I have calculated earlier [end of digression].

With China's BRI expanding towards an "around-the-world" concept, including Latin America and Oceania, the Panama Canal, under its western control, cannot fail to be a risk factor for China, similar to that of the Malacca Strait (cf. below). The Americans too would not mind at all had an alternative to Panama Canal existed. As always, when big money is involved, ideas crop up: one, defunct now, was the Nicaragua Canal. Another, today, is a rather futuristic concept in Northern Colombia, currently in search of investors to finance it. The project, under the name PILA, developed by the Miami-based company Zergratran,[37] connects the Pacific with the Atlantic Ocean via a one, 130 km, underground tunnel. Post-Panamax ships would unload containers at a fully automated Pacific port (and *vice versa* in the Atlantic). Containers would then be placed on special Maglev (magnetic levitation) platforms which would take them, in 30 minutes, to a sister port on the Atlantic, to be loaded onto ships again.

The Nicaragua Canal

Although defunct since 2018, the Nicaragua Canal warrants attention for a number of reasons. Nicaragua is one of the poorest countries in the world and is the country of the *Sandinista* Daniel Ortega: the revolutionary Marxist president of the 1980s turned pro-business in his second term in 2007. The political history of the country, the Ortega revolution of 1979, overthrowing the dictator Anastasio Somoza, the fight against the pro-US "contras" rebels, and the merciless policies of the US (trade embargo, mining port entrances, and the

[37] I guess meaning Zero Gravity Transportation.

most recent Biden prohibition of Ortega and his officials from entering the US) makes fascinating reading to the political scientist.

The idea of cutting out a canal through Nicaragua, connecting the Pacific to the Atlantic Ocean (Caribbean Sea) (Figure 3.4), as an alternative to Panama, was not new, having been considered for centuries. In recent years, the possibility of hosting ships larger than the Panama limitations had given the plan heightened impetus and it was adopted with enthusiasm by the Ortega administration. Chinese funding emerged (up to $50 billion) through the Hong Kong-based company HKND.

The proposed sea-level canal, which, unlike Panama, required no locks, would have a length of 280 km, far longer than the Panama Canal, cutting through Lake Nicaragua, Central America's biggest fresh water lake. At the time, I believed that the US would support the idea, which was offering them much shorter distances westwards to Asia (Nicaragua being north of Panama), i.e. much closer to the US exports of natural gas to Asia: a trade presently accounting for about 40% of Panama's westward traffic. In the event, however, politics trumped economics and the US refused to embrace a project controlled by China and competing with its own interests in Panama.

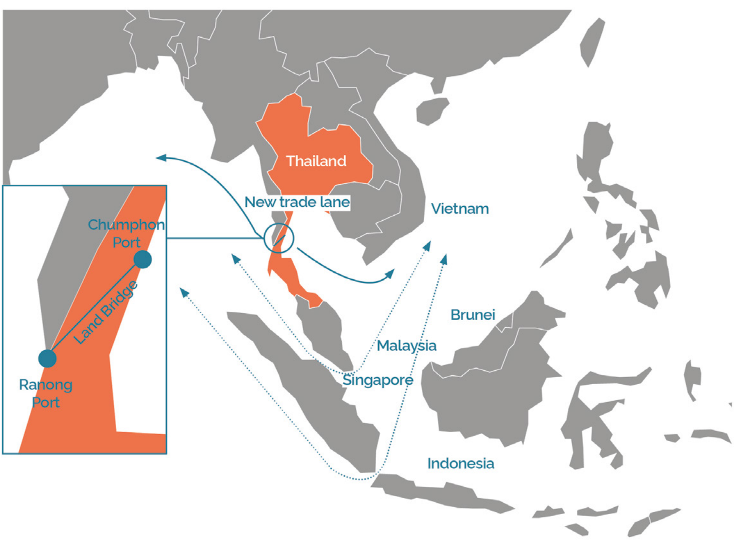
Eventually, Chinese interest waned and in 2018 HKND announced that it no longer had an interest in the project. The true reasons for that decision are not known but one could imagine them. Publicly, however, economic and technical problems were cited, alongside strong opposition from international environmental organizations, such as Friends of the Earth and many others. Indeed, the impacts of the canal would have been significant in terms of displacements of population, peasant communities, wildlife and ecosystems. Once again, a poor developing country proved unwilling to strike a balance between environmental sustainability and economic development.

The Malacca Strait

The Malacca Strait has been one of the world's most important and thus busiest waterways, for time immemorial serving the east-west trade routes (Figure 3.9). Roughly 80,000 commercial ships transit the strait each year and the heavy traffic gives rise to accidents, pollution and ecological degradation. These, together with territorial disputes and the longstanding problem of piracy in the strait, remain unresolved, despite the conscientious efforts of the strait's three lateral states (Singapore, Malaysia and Indonesia) and of the international community (US, Japan, Korea).

Deviating from the strait is only possible southwards through the *Sunda Strait* (Figure 3.10), between the Indonesian islands of Sumatra and Java which, however, adds 1,000 to 1,500 kilometers to the route, or two days of sailing.

Fig. 3.10 - Malacca Strait, the Kra Canal (and land bridge) and the Sunda Strait



The Kra Canal

Cutting out a sea-level[38] canal, similar to the Nicaragua Canal or the Colombian PILA, across Thailand's Kra Isthmus would connect the South China Sea to the Indian Ocean (Figure 3.9). The idea goes back four centuries. More recent discussions, however, have been invariably frustrated, mostly on grounds of national sovereignty, relating to concerns about surrendering control to foreign investors, notably China, which has always been eager to finance the works, due to its interest in bypassing the risky, West-controlled Malacca Strait. A cursory look at Figure 3.9 immediately shows that the main beneficiary from the canal would be China and its ports (e.g., Shenzhen and Guangzhou), to the detriment, however, of Singapore and the Malaysian ports of Tanjung Pelepas and Port Klang. In this regard, the risk of upsetting the balance between ASEAN countries has been another consideration of Thai governments, also taking into account a rather misguided US reluctance to concede trade control to China.

The Kra Canal would shorten east-west distances, say, from Shenzhen to Rotterdam, by 1,200 km or, depending on cruising speeds, by two to three days of sailing. At present, the Kra Canal might make even more sense in view of the Malacca Strait chokepoint and its above challenges.

Projections, plans and budgets have been plenty over the years, in principle envisioning a canal of 100 km, 400 m wide, and 25 m deep, i.e., an artificial waterway that would allow passage of the biggest of ships. All this is now shelved; recently (2023), the Thai Government enthusiastically proposed a $28 billion "land bridge", rather than a canal, and, once again, China has proved willing to finance it.[39] The project involves a 90 km rail and motorway system, connecting the two ports of Ranong and Chumphon, where two new terminals would be

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[38] That is, requiring no locks.

[39] As I understand from discussions with colleagues in Thailand, India may also be interested in taking part in the financing.

built (accounting for the biggest chunk of the above budget). According to the Thai PM, the land bridge would now save 7 to 8 days of sailing.

A Final Brushstroke

The above narrative, written in my unusual style that often scorns academic orthodoxy in writing norms, makes two final points, or at least I hope it does. Firstly, expending scarce resources on pharaonic projects, often as instruments of a pointless geopolitical competition, is wrong. Public debt is a bomb on the foundations of the planet which, if it ever explodes, will have unpredictable consequences. Secondly, a lot of discussions and policy interventions have been taking place lately, rightly so, on the health of our oceans and the worrisome ramifications of global warming. In our noble pursuit of a sustainable planet, in our eagerness, anxiety and often desperation to finally do something about our grave environmental predicament, we tend to forget that the oceans are the lifeline of trade; and that trade, this basic ingredient of our welfare, takes place mostly by sea. In this sense, our oceans are not "heated" only by global warming but also by everything else – like the chokepoints I have described above – which obstruct the free flow of trade. This is something we should always keep in mind, for without economic "survivability", sustainability is a mere empty shell; an ocean without fish.

4. Deglobalization: Could It Help to Decarbonize Global Supply Chains?

Alan McKinnon

Of the many trends likely to reshape global supply chains over the next decade two merit particular attention: deglobalization and decarbonization. They are usually discussed separately, but in this short article I will explore the possible connections between them. Would a reversal of several decades of globalization be likely to help or hinder the pursuit of Net Zero supply chains, or perhaps have little overall impact on their carbon emissions?

Deglobalization has been defined as

> the movement towards a less connected world, characterised by powerful nation states, local solutions, and border controls' and precipitated by the recent growth of protectionism, problems with supply chains, the diminishing role of global institutions, geopolitical shifts, technological rivalry and falling foreign investment, as well as energy and food crises.[1]

This suggests that deglobalization is largely a reaction to a series of short-to-medium term shocks, sometimes called a "polycrisis", that have occurred in quick succession and are collectively threatening to undermine several decades of globalization. One can also take a longer-term view of the development of the global economy and see deglobalization as a structural

[1] M. Kornprobst and J. Wallace, *What is Deglobalisation*, Chatham House, London, 2022.

readjustment to trends such as the narrowing of international labor cost differentials, which was one of the prime drivers of globalization. Within this longer time-frame, supply chains may have become over-extended and hence too vulnerable to the range of disruptions that we have witnessed in recent years. In an effort to make them more robust and resilient, in what is now a much more turbulent world, companies are more actively relocalizing, reshoring, backshoring and near-shoring – or so the argument goes.

The purpose of this chapter is not to debate whether or not deglobalization is happening or likely to occur in the future. This is discussed at length by others. Manners-Bell (2023), for example, argues that

> the fragmentation of supply chains seems inevitable in the current political climate. Neo-liberal dreams of a "flat world" in which trade fosters growth and promotes democracy have been rejected for a "Balkanised" structure based instead on domestic political priorities and geo-political ambitions.[2]

On the other hand, the results of the latest DHL Global Connectedness Survey "contradict prevalent narratives about the world entering a period of deglobalization", though its definition of connectedness includes flows of people, capital and information as well as physical trade.[3] The issue addressed by this paper is the extent to which deglobalization might help companies to decarbonize their supply chains, if it were to happen at scale.

Carbone and Moatti (2021) argue that "it is necessary to move beyond an overly simplistic view whereby reshoring is synonymous with sustainability".[4] One feature of this over-

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[2] J. Manners-Bell, *The Death of Globalization: How Politics, Ethics and the Environment Are Shaping Global Supply Chains*, Sea Pen Books Ltd, 2023, p. 45.

[3] S.A. Altman and C.R. Bastian, *DHL Global Connectedness Report 2024: an In-Depth Analysis of the State of Globalization*, DHL and NYU Stern School of Business, 2024.

[4] V. Carbone and V. Moatti, *Bringing it all back home: Is reshoring sustainable?*, ESCP

simplification is the tendency to present deglobalization as a shortening of supply chains. This can give the impression that they are linear and comprise few links. In reality, supply chains for manufactured products typically connect many production and logistics locations around the world at which value is added incrementally to raw materials, components, sub-assemblies and ultimately the finished product, along what Porter (1985) called "value chains".[5] A supply chain can be regarded as a physical manifestation of a value chain, comprising factories, warehouses and terminals and the movement of freight between them, though opinions differ on the definitions of the two terms.[6] The freight transport intensity of the global economy is determined as much by the number of links in supply chains as by their average length. Wang et al (2022) calculated that in 2015 the average ton of international trade (based on its consumption weight) travelled 20,000 km on an end-to-end supply chain basis.[7] This could be used as a crude indicator of the transport intensity of the international trading system. According to Wang et al this increased by a quarter between 1995 and 2015.

Discussion of the logistics of deglobalization tends to focus on distance, but often just on the length of the last link in the chain between the final assembly point and the market. This overlooks the ways in which deglobalization would affect the complexity and configuration of the dense network of supply chains that criss-crosses the planet. In 2015, almost three-quarters of international freight movement (in ton-kms) was of intermediate trade on upstream links in cross-border supply

Impact Paper No 2021-10-EN, ESCP Business School, Paris, 2021.

[5] M. Porter, *Competitive Advantage: Creating and Sustaining Superior Performance*, Free Press, New York.

[6] M. Holweg and P. Helo, "Defining value chain architectures: Linking strategic value creation to operational supply chain design", *International Journal of Production Economics*, vol. 147, 2014, pp.230-38.

[7] Y. Wang, "The volume of trade-induced cross-border freight transportation has doubled and led to 1.14 gigatons CO2 emissions in 2015", *One Earth*, vol. 5, no. 10, 21 October 2022, pp. 1165-177

chains rather than the final link to the country in which the finished products were consumed.[8] Long term growth of the trade in "intermediate" goods has been closely associated with the development of global value chains.[9] The carbon intensity of the activities performed at the multiple nodes in these chains can exert a much greater influence on the carbon footprints of traded products than the intervening transport operations. These activities are a mix of production,[10] storage and materials handling, with production being by far the most carbon-intensive.

The remainder of this chapter examines the possible impact of deglobalization on GHG emissions from freight transport and production operations within global supply chains.

Freight Transport Emissions

Stojanovic´ et al (2021) acknowledge that "the literature on emissions by international freight transport is limited, with a lack of quantitative models on sustainable supply chains".[11] The main quantitative modelling of these emissions at a global level has been undertaken by the International Transport Forum (ITF). Unlike most other trade-transport modelling exercises, its models include the domestic movement of import and export traffic within countries, recognising that "goods transported by road or rail from (or to) centers of production or consumption to (or from) ports are a significant element

[8] Ibid.

[9] T.J. Sturgeon and O. Memedovic, *Mapping Global Value Chains: Intermediate Goods Trade and Structural change in the World Economy*, United Nations Industrial Development Organisation, Vienna, 2011.

[10] The term "production" is used here to describe a range of activities altering the physical character of a product, including processing, refining, assembly, manufacture, recycling and packaging.

[11] D. Stojanovic, J. Ivetic and M. Velickovic, "Assessment of International Trade-Related Transport CO2 Emissions-A Logistics Responsibility Perspective", *Sustainability*, vol. 13, no. 3, 2021, p. 1138.

of international freight".[12] According to its latest analysis, international freight flows in 2019 accounted for almost three-quarters of all freight movement and 42% of total CO_2 emissions from freight transport.[13] Their share of emissions was much lower than their proportion of freight movement because over 80% of international ton-kms were moved by ship,[14] a mode whose average carbon intensity, at around 6g per ton-km,[15] is roughly a quarter that of all freight transport. ITF predicts that, if "existing policies and forthcoming policy commitments in national and regional governance directives, government strategies and laws were fully implemented, in what it calls its "current ambition" scenario, total CO_2 emissions from international freight transport would rise by 27% by 2050. This would seriously breach the commitments by governments and businesses to be Net Zero by 2050 or earlier. Net Zero pledges currently cover 92% of the global economy and the vast majority of them have a target date of 2050 or earlier.[16] If CO_2 emissions from the movement of international trade were to rise 27% by 2050, applying the Net Zero principle to freight transport would entail the removal of around 1.9 billion tons of CO_2 annually from the atmosphere. When set against the mere 10,000 tons sequestered by carbon dioxide removal (CDR) in 2023,[17] the embryonic state of current "negative emission" technologies and serious concerns about the long-term cost and feasibility of planetary scale CDR, this would be a highly risky strategy. Intensifying efforts today to mitigate international

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[12] International Transport Forum (ITF), "The Carbon Footprint of Global Trade: Tackling Emissions from International Freight Transport", International Transport Forum, OECD, Paris, 2015.

[13] International Transport Forum (ITF), *Transport Outlook 2023*, International Transport Forum, OECD, Paris, 2023.

[14] UN Conference on Trade and Development (UNCTAD), *Review of Maritime Transport 2021*, Geneva, 2021.

[15] International Maritime Organisation (IMO), *Fourth Greenhouse Gas Study*, London, 2020.

[16] Net Zero Tracker, *Data Explorer*, 2024.

[17] International Energy Agency (IEA), *Direct Air Capture*, Paris, 2023.

freight-related emissions would be a much cheaper, quicker and safer option.

ITF models a "High Ambition Scenario" in which carbon emissions from transport would plummet over the next three decades. This could depress emissions from international freight flows by 93% between 2020 and 2050, still leaving around 100 million tons per annum to be counter-balanced by carbon sequestration, but this would be a more manageable task if negative emission activities ramp up as expected. According to ITF modelling, this dramatic decarbonization of international freight movement could be achieved mainly by a combination of efficiency improvements, modal shift and a more rapid transition to renewable energy. The only reference in the High Ambition Scenario to the volume of freight movement contracting is in connection with the reduction in "the trade in and consumption of petroleum- and coal-based commodities" which is a *sine qua non* for the "defossilization" of the global energy system. Since much of the movement of fossil fuel is transcontinental, its phase-out can be considered a form of deglobalization, though the creation of a new low-carbon energy infrastructure of wind-turbines, solar panels, hydro- and nuclear power and green-hydrogen electrolysers over the next few decades will rely heavily on the global sourcing of materials, components and equipment.

No reference is made in the High Ambition Scenario to broadly-based deglobalization as a means of constraining the future demand for international freight transport services. It is recognized that a key policy instrument in the Scenario, the imposition of a high price on carbon emissions, would "impact... on demand patterns (for example, regionalization and trip length)", but modelling its effects would require "further work".[18] If deglobalization were to become a pronounced trend, with or without carbon pricing, what is the likelihood that it

[18] International Transport Forum (ITF), *Transport Outlook* 2023, OECD, Paris, 2023, p. 104.

would cut freight-related emissions, or at least slow their growth, by reducing the distance that each unit of trade is transported? This question raises several issues.

1. For most businesses, the shortening of supply lines, and deglobalization in general, is being motivated mainly by objectives other than decarbonization. Various studies have explored companies' motives for reshoring their production and make little or no reference to the environment, let alone carbon emissions.[19] When compared with the desire to minimize dependence on suppliers in risky locations, to reduce the probability of supply chain disruption and to improve supply chain resilience, emission reductions can seem a marginal co-benefit. They are currently not a major driver of deglobalization.
2. Many of the supply chain risks which deglobalization supposedly aims to mitigate are country- and supplier-specific and can have a relatively weak correlation with the distance over which products are transported. Prior to the pandemic, long haul shipping and air cargo services were fairly reliable. For example, container shipping services were achieving average monthly schedule reliability levels of 65-80% in early 2020, with all but extreme delays buffered by inventory or slack in logistics/production processes. The reliability level then plunged from 75.3% in July 2021 to 35.6% in July 2022.[20] It was rebounding until the disruption to container services in the Red Sea in October 2023 reversed the trend (Sea Intelligence, 2024). The Covid-related spike in container shipping and air cargo freight rates in 2021 and 2022, inflating the former by as much as

[19] E.g. A.V. Benstead, M. Stevenson, and L.C. Hendry, "Why and how do firms reshore? A contingency-based conceptual framework", *Operations Management Research*, vol. 10, 2017, pp. 58-103.

[20] Z. Yue and J. Mangan, "A framework for understanding reliability in container shipping networks", *Maritime Economics and Logistics*, 2023.

ten-factor on some trade routes, was very exceptional. Modelling by Ferrari et al (2023) of

> the 2021-22 surge in rates for containerized and bulk (shipping) costs' shows how rising maritime transport costs tend to reverse the trend towards globalization of international trade and favour localization.[21]

This inflationary episode was short-lived, however, reversing during 2023 and returning rates to their pre-pandemic levels. For instance, the Freightos Global Container Index of average container shipping rates was almost identical on 7 June 2019 ($1,362) and 2 June 2023 ($1,380). So the transport cost pressure on companies to source more locally, which greatly strengthened in the aftermath of the pandemic returned to historically low levels.

As global logistics systems recovered from the pandemic, the risks and costs of moving stuff transcontinentally appeared to be weakening as justifications for deglobalization and with them the pressure to shorten delivery distances. The recent terrorist attacks on international shipping in the Red Sea reversed these trends, provoking another round of media commentary on the vulnerability of globalised supply chains and the possible resilience benefits of deglobalization. This time, distance was at the heart of the debate because risk-mitigation entailed routing vessels sailing from the Far East to Europe and the East Coast of North America around the Cape of Good Hope, typically adding over 3,000 nautical miles to their voyages. This, for instance, represents a 30% lengthening of voyages between Shanghai and Rotterdam.[22] For much of the

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[21] E. Ferrari, P. Christidis, and P. Bolsi, "The impact of rising maritime transport costs on international trade: estimation using a multi-region general equilibrium model", *Transportation Research Interdisciplinary Perspectives*, vol. 22, 2023, p. 100985.

[22] T. Notteboom, A. Pallis, and J.-P. Rodrigue, *Port Economics, Management and*

22% of containerised sea trade that normally transits the Suez canal,[23] the percentage increase in carbon emissions has exceeded the proportional increase in distance because shipping lines have accelerated their vessels to cut the additional transit time, for both service quality and capacity utilization reasons. The practice of slow steaming, which since 2008 has been responsible for much of the decline in the carbon intensity of shipping,[24] has been relaxed for many of the vessels circumnavigating the African continent. Analysis by Transport & Environment estimates that the diversion of shipping around the southern tip of Africa could be emitting an additional 163,000 tons of CO_2 per day,[25] roughly equivalent to the daily emissions of Portugal.[26] The response of international shipping to the Red Sea attacks has clearly made the global supply chains of their client businesses more transport- and carbon-intensive, in terms of the distance travelled and amount of CO_2 emitted per ton of traded commodity. If this Red Sea crisis were to persist, the combination of higher freight rates (currently around 2-3 times above the mid-2023 rate) and longer transit times (around 8-10 days longer) would be likely to promote some reshoring of production and sourcing from the Far East to Europe. This deglobalization, however marginal, would unquestionably yield transport-related carbon savings. In this case, they would accrue from one deep-sea link in the supply chains of the reshoring businesses.

Policy, Routledge, New York, 2022.

[23] UN Conference on Trade and Development (UNCTAD), *Navigating Troubled Waters*, UNCTAD Rapid Assessment, February 2024.

[24] IMO (2020).

[25] Baker (2024).

[26] European Commission, "EDGAR - Emissions Database for Global Atmospheric Research", 2024.

3. There is little evidence of the average number of links in multi-tier supply chains reducing, what in the distribution channel literature they call "disintermediation". This would require a vertical integration of upstream production processes. In sectors, such as automotive[27] and electronics, the opposite seems to be the case, partly because

> as products have become more complex over time, they require components from an expanding set of new suppliers. As a result, supply chains have become more interconnected...[28]

Where, for resilience reasons, a supply chain is 're-routed' away from a country or region posing a heightened risk, its number of links is likely to remain the same or increase. As Crabtree (2023) points out,

> while shifting supply chains around the world appears to leave the west less reliant on China, the continuing need for components that still mostly come from there means the fundamental vulnerability remains.

The freight transport intensity of the supply chain can also remain much the same or even increase where, for example, a final assembly operation moves from China to Vietnam or Malaysia, but some of the inbound components are then delivered from the original component suppliers in China, adding an additional link to the supply chain. This is more akin to the process

[27] The future replacement of internal combustion engine (ICE) vehicles by electric vehicles (EVs) will reverse this trend, substantially reducing the number of components and upstream suppliers. Sharma (2018) estimated that the average proportion of value added by component suppliers will drop from 50-55% for an ICE car to around 35% to 40% for an EV. A. Sharma, "EVs and the impact on the automotive value chain", *Autocar Professional*, 29 March 2018.

[28] V. Gaur, N. Osadchiy, and M. Udenio, "Research: Why It's So Hard to Map Global Supply Chains", *Harvard Business Review*, 31 October 2022.

that the WTO (2023) calls "reglobalization", which reroutes value chains but does not necessarily compress them geographically or reduce their complexity.

If deglobalization did significantly reduce the average distance that each international consignment was moved on an end-to-end supply chain basis, what level of carbon savings might we expect? As mentioned earlier, over four-fifths of the international trade in goods is moved by sea and shipping is by far the least carbon-intensive freight transport mode. UK government data indicates that moving containers, general cargo and bulk commodities by sea has a carbon intensity, respectively, of 16, 13 and 4 g of CO_2 per ton-km, by comparison with 28 g for railfreight, 97 g for an articulated truck and 539 g for long haul air cargo DESNZ and DBEIS (2023).[29] This means that per ton of product transported, shortening a containerised maritime movement by 1,000 km would save only 16 kg of CO_2 as opposed to around 100 kg in the case of trucking and over half a ton of emissions from air cargo. For global supply chains heavily dependent on-air cargo, switching less time-sensitive consignments to surface transport modes would have a vastly greater impact on carbon emissions than any supply chain shortening.

Taking a longer-term perspective, one can compare the time it would take for businesses to deglobalize their supply chains with the projected rate of maritime decarbonization. Both are medium-to-long term processes. Relocating production operations, finding and vetting new suppliers, building new business relationships and creating new logistics systems can take many years, during which time the average carbon intensity of shipping, and other freight modes, may drop quite sharply. The IMO (2023) has set a target for reducing the already low carbon intensity for shipping by 40% by 2030

[29] *Department* for *Energy Security* & *Net Zero (*DESNZ) and Department for Business, Energy & Industrial Strategy (DBEIS), *Greenhouse gas reporting: conversion factors 2022*, 2023, London.

(against a 2008 baseline), by a combination of energy efficiency improvements and the replacement of fossil fuel with low carbon alternatives.[30] To get onto an emission trajectory leading to Net Zero shipping by 2050, total maritime CO_2e emissions would need to half from 1.2 GtCO_2e in 2022 to around 0.6 GtCO_2e by 2030.[31] Neither this nor the IMO's carbon intensity target are close to being achieved, though the rate of maritime decarbonization is predicted to accelerate. By reducing the total demand for international shipping in the medium to long term, deglobalization could reinforce this trend

Production Emissions

Roughly two-thirds of the embedded emissions in international trade come from production processes rather than international freight transport.[32] This proportion varies enormously, from bulk agriculture at just over 90% to metal products at 10%.[33] For a range of manufactured products likely to be subject to deglobalization pressures, such as textiles, electronic equipment, plastic and paper products, the percentage varies between 40% and 70%. However, the WTO data set upon which this cross-commodity comparison of the split between production- and transport-related emissions is based contains rather old statistics and is not necessarily a good guide to the current situation. The WTO (2021) acknowledges that its method of calculation "does not capture the change in emissions intensity of transport from 2004 to 2017".[34] This is significant because it is estimated that

[30] IMO (2023).

[31] Mærsk Mc-Kinney Møller Centre, *Maritime Decarbonisation Strategy 2022: A Decade of Change*, Copenhagen, 2023.

[32] A. Cristea, D. Hummels, L. Puzzello, and M. Avetisyan, "Trade and the greenhouse gas emissions from international freight transport", *Journal of Environmental Economics and Management*, vol. 65, no. 1, 2013, pp. 153-173.

[33] World Trade Organisation (WTO), "Trade and Climate Change: Carbon Content of International Trade", Information Brief no.4, Geneva, 2021.

[34] Ibid.

the carbon intensity of international shipping fell by between 29% and 32% (depending on the method of calculation) between 2008 and 2018.[35] This may have reduced the transport share of GHG emissions from international trade and increased the relative importance of international variations in the carbon intensity of production. A sector-level analysis by La Migne and Ossa (2020), found that sourcing trade from countries with the lowest carbon intensities, ignoring the distances separating them, would cut "global production emissions by 6.3%".[36] Would deglobalization be likely to promote greater sourcing of traded products, particularly those with higher carbon content, from those countries with less carbon-intensive production?

This would partly depend on the correlation between factors promoting deglobalization and the average carbon intensity of a country's production. As discussed earlier, one major factor is the desire to minimise supply chain exposure to country-specific risk. This makes the relationship between the risk that a country poses and the carbon intensity of its production fairly critical. For deglobalization to contribute significantly to supply chain decarbonization, it would be beneficial for countries deemed to be risky sources of traded products to have a relatively high carbon intensity. Removing them from a global supply chain would then simultaneously cut risk and emissions. In reality, this risk-emission balance varies widely by country. In the case of climate risk, there is a fundamental imbalance in many less developed countries between high exposure to extreme weather events and very low levels of GHG emission per capita or per $ of GDP. For example, Bangladesh is ranked the "seventh extreme disaster risk-prone country in the world" in terms of the Climate Vulnerability Index of the UN Development Programme (2023), but in 2022 its citizens emitted only one eighth of the annual per capita CO_2 emissions

[35] IMO (2020).

[36] M. La Migne and R. Ossa, *Buy Green not Local: How International Trade Can Help Save Our Planet*, Kühne Center Impact Series, University of Zurich, 2020.

of the global population.[37] Superficially, China might be considered to exhibit a close correlation between risk and carbon emissions. Everstream Analytics (2023) recently gave China a 90% risk score for the frequency of delays and cancellations by Chinese suppliers while much has been written about the growing geopolitical risk posed by sourcing from China.[38] The country has also had a poor environmental record. A multi-criterion assessment by Yale University assigned China a low Environmental Protection Index of 28.4 in comparison with, respectively, 77.7, 62.4 and 51.1 for the UK, Germany and the US.[39] So, if deglobalization involves reducing the dependence of value chains on China as a risk mitigation strategy, there might be emission-reduction co-benefits. These benefits may be short-lived, however, and diminish rapidly during the time scale that would be required for extensive deglobalization. It was estimated that emissions from China's power sector, which strongly influence the average carbon intensity of the country's manufacturing operations, would peak in 2023 and then drop steeply over the next ten years.[40] China is also the largest source of exports of green products. In 2021, it held a 14.6% share of the global market in these products,[41] a proportion that is predicted to rise. So disconnecting China from global supply chains to minimise their geopolitical vulnerability could impede decarbonization efforts around the world.

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[37] Global Carbon Budget (2023); Population based on various sources (2023) – with major processing by Our World in Data. https://ourworldindata.org/grapher/co-emissions-per-capita?tab=table&time=latest

[38] L. Bednarski, S. Roscoe, C. Blome, and M.C. Schleper, "Geopolitical disruptions in global supply chains: a state-of-the-art literature review", *Production Planning & Control*, 2023.

[39] M.J. Wolf, J.W. Emerson, D.C. Esty, A. de Sherbinin, Z.A. Wendling, et al., *2022 Environmental Performance Index*, Yale Center for Environmental Law & Policy. New Haven, CT, 2022.

[40] D. Murtaugh, "Solar and EV Booms Push China Toward Energy Tipping Point", *Bloomberg Newsletter*, 30 May 2023.

[41] Xu et al. (2023).

Conclusion

More localized sourcing is often advocated as a means of cutting global carbon emissions. Whatever its corporate motivation, deglobalization would therefore be welcomed by many environmentalists as a carbon-reducing trend. In practice, the relationship between deglobalization and decarbonization is more complex than it is generally portrayed. Seeing the geographical compression of global supply chains as the main deglobalization mechanism for cutting emissions overlooks several important points; that over four-fifths of international trade is moved by the transport mode with by far the lowest carbon intensity (shipping), that over a realistic time-scale for significant deglobalization to occur that carbon intensity is likely to drop quite sharply and that, for the international trade in many products likely to be subject to reshoring pressures, transport-related emissions represent less than 40% of total embedded emissions. More important than the distance-reducing effects of deglobalization will be the extent to which it reconfigures the pattern of international trade to increase sourcing from countries and regions with relatively low carbon production.

This chapter has explored the causal relationship between deglobalization and decarbonization in one direction. It has not considered the possible impact of the decarbonization of both freight transport and production operations on the global trading system. According to Baresic and Palmer (2022), "current estimates in line with IMO Initial Strategy ambitions put the total additional capital needed for shipping's decarbonization at US$ 1-1.4 trillion".[42] The recovery of these costs in higher freight rates, would significantly inflate the price of shipping services, though given the past sensitivity of the volume of international trade to transport costs, the net effect of even quite large hikes

[42] D. Baresic and K. Palmer, *Climate Action in Shipping: Progress towards Shipping's 2030 Breakthrough*, UMAS, London, 2022.

in rates may be modest. Modelling by UNCTAD (2023), for example, found that a 50% increase in "maritime logistics costs" would reduce international trade flows by only 0.6%.[43] Some of this reduction might be due to deglobalization, but much of it simply to a thinning of flows within the existing pattern of trade. This analysis suggests, however, that, at least in economic terms, any feedback loop between decarbonization and deglobalization might be relatively weak.

Given the current state of knowledge, it would be premature to draw firm conclusions about the evolving relationship between deglobalization and decarbonization. Much more research is needed to improve our understanding of the interaction between these two supply chain megatrends.

[43] UN Conference on Trade and Development (UNCTAD), *Review of Maritime Transport 2023*, Geneva, 2023.

5. Harnessing Clean Hydrogen Mobility: Opportunities and Challenges

Nicola De Blasio

The global transition to a low-carbon economy and adopting the needed clean energy technologies at scale will significantly impact existing value chains[1] and transform production-to-consumption lifecycles. Regulatory and business models must rapidly evolve to manage the resulting substantial cost challenges and dramatic shifts in stakeholder interactions while continuing to create value.

While hydrogen has long been a staple in the energy and chemical sectors, the emergence of clean hydrogen[2] is poised to be a game-changer in the world's transition toward a carbon-free future. Its adoption at scale holds the key to decarbonizing energy-intensive industrial processes, such as steel and cement production, whose emissions are hard to abate.[3,4] However,

[1] Unlike the term supply chain, which is typically used to define a set of operational relationships designed to benefit a single stakeholder and deliver products or services, the term value chain refers to a more conceptual design of business relationships between stakeholders that support the development and adoption of a market or technology at scale.

[2] Clean hydrogen is defined as hydrogen produced either by renewable or nuclear power or by fossil fuels using carbon capture and storage (CCS).

[3] F. Pflugmann and N. De Blasio, "The Geopolitics of Renewable Hydrogen in Low-Carbon Energy Markets", *Geopolitics, History, and International Relations*, vol. 12, no. 1, 2020, pp. 9-44.

[4] L. Eicke and N. De Blasio, "Green hydrogen value chains in the industrial sector - Geopolitical and market implications", *Energy Research & Social Science*,

to take advantage of the associated economic opportunities, stakeholders must rethink their roles in a new energy landscape and define strategic industrial policies accordingly.

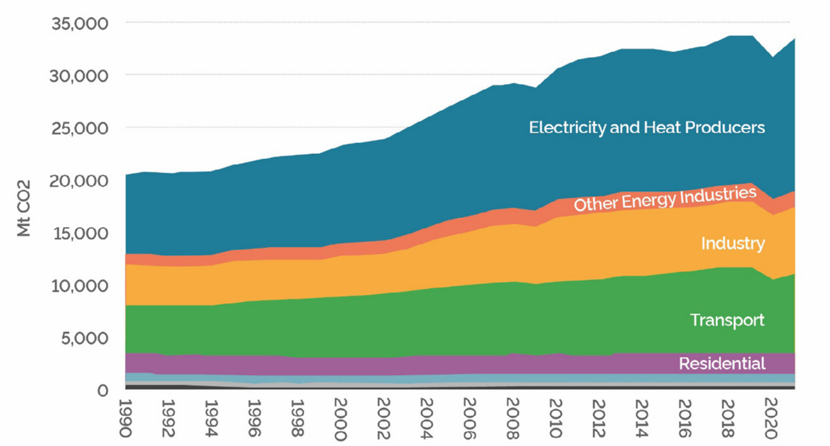
As both public and private stakeholders become increasingly committed to addressing climate change, they are also placing greater emphasis on the deep decarbonization of mobility in sectors such as aviation, shipping, rail, and long-distance road transportation. Areas were shifting to electricity as the preferred energy vector while decarbonizing its production may not be immediately feasible. At the same time, the adoption of clean hydrogen will depend on more than just its environmental benefits; economic, policy, technological, and safety factors must also be addressed.

Overall, transportation is the second-largest producer of global carbon dioxide (CO_2) emissions, after electricity and heat generation (see Figure 5.1),[5] and one of the most challenging sectors to decarbonize due to its distributed nature and the advantages provided by fossil fuels in terms of high energy densities, ease of transportation and storage. Greenhouse gas emissions from transportation primarily come from burning fossil fuel in cars, trucks, ships, trains, and planes. Globally, over 94% of transportation fuels (gasoline, diesel, and jet kerosene) are petroleum-based.

vol. 93, no. 102847, 2022.

[5] International Energy Agency (IEA), "Data & Statistics", 2023.

FIG. 5.1 - CO_2 EMISSIONS BY SECTOR, WORLD, 1990-2021



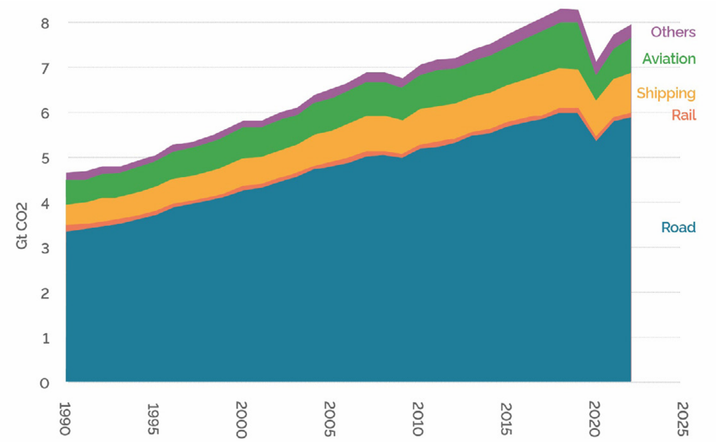
Source: IEA (2023)

According to the International Energy Agency (IEA), in 2022, global CO_2 emissions from transport grew by almost 3%, reaching 8 Giga tons (Gt) and nearly reaching pre-pandemic levels.[6] Aviation was responsible for much of this increase, as air travel rebounded from pandemic lows. See Figure 5.2 for a detailed analysis of global CO_2 emission from transport by segment.

It is key to note that while hydrogen holds significant promise for accelerating the overall decarbonization of mobility, its adoption will complement rather than compete with other decarbonization strategies. Figure 5.3 summarizes for which segments different technologies – battery electric vehicles (BEVs), hydrogen fuel cell electric vehicles (FCEVs), and vehicles running on bio- and/or synthetic fuels – are most applicable.

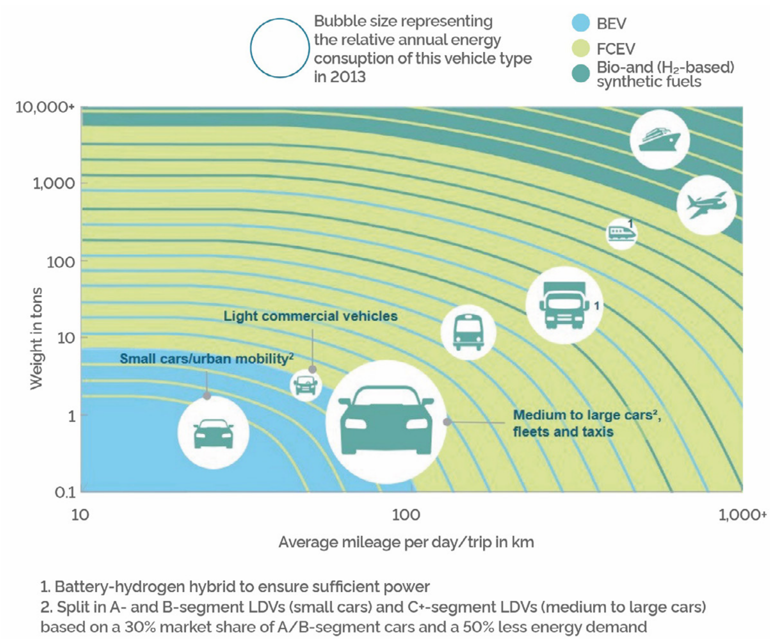
[6] IEA (2023), "Greenhouse Gas Emissions from Energy."

Fig. 5.2 - 2022 global CO_2 emissions from transport by segment



Source: IEA (2024) and author's elaboration

Fig.5.3 - Hydrogen applications in the mobility sector



Source: Hydrogen Council 2017

The Hydrogen Molecule. Production and Applications

Hydrogen is the most abundant element in the solar system but only occurs in compound form on Earth. Thus, hydrogen must be produced from molecules containing it through specific processes such as thermo-chemical conversion, biochemical conversion, or water electrolysis.

Annual global hydrogen production today stands at over 75 million tons (Mt) and stems almost entirely from natural gas (steam gas reforming) and coal (coal gasification).[7] Although hydrogen burns cleanly as a fuel at its point of use, producing it from fossil fuels without carbon capture and sequestration (CCS) simply relocates emissions. Hence, to reap hydrogen's full environmental benefits, it must be produced from zero-carbon electricity through water electrolysis, an electrochemical process that splits water into hydrogen and oxygen (green or renewable hydrogen).

Today, hydrogen is mainly used in petroleum refining and fertilizer production, while transportation and utilities are emerging markets. Yet, with growing emphasis on its decarbonization potential across sectors, hydrogen demand is projected to increase considerably in the coming decades. While recent reports vary in estimating demand by 2050, clean hydrogen could capture up to 14% of future global energy markets.

Overall, two factors will determine hydrogen's rate of adoption: competitiveness of production costs and deployment of enabling infrastructure at scale. Today, renewable hydrogen is two to three times more expensive than hydrogen produced from fossil fuels.[8] Although short-term production costs have risen significantly across the board, particularly for renewable

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[7] International Renewable Energy Agency (IRENA),"Energy Transition - Hydrogen", 2024.

[8] International Renewable Energy Agency (IRENA), "Making Green Hydrogen a Cost-Competitive Climate Solution", 2020.

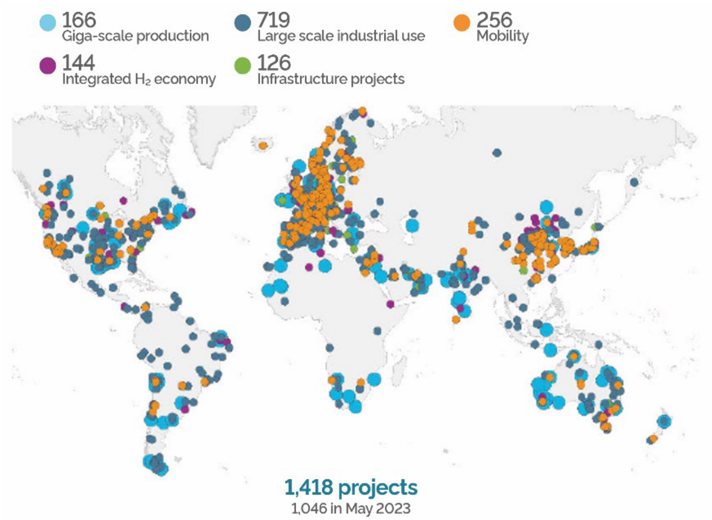
hydrogen, driven by higher capital, material, and labor costs, they are still expected to decline to 2.5 to 4.0 dollar per kilogram ($/Kg) by 2030, from today's 4.5 to 6.5 $/Kg.[9] This thanks to technology improvements, economies of scale, cost reductions along value chains, and carbon pricing policies.

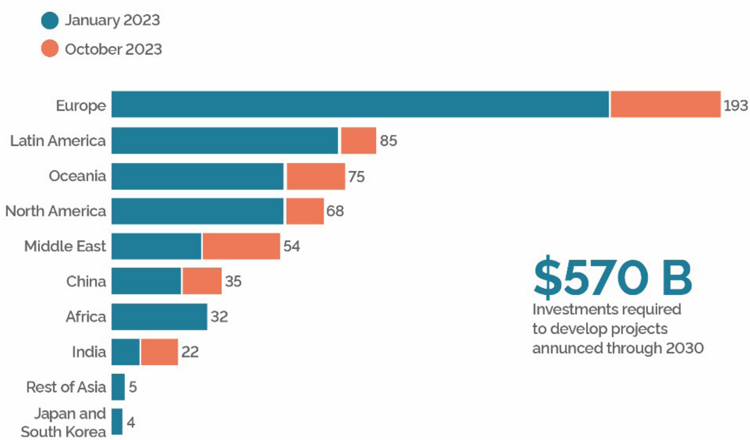
Despite these challenges, the project pipeline is growing fast, with Europe, China, and North America leading the hydrogen race. As of October 2023, more than 1,400 projects had been announced globally, equating to $570 billion in investments (see Figure 5.4).

From a market perspective, clean hydrogen can be used in both stationary and mobility applications. As a readily dispatchable means of storing energy, hydrogen can help address growing intermittency and curtailment challenges associated with expanded renewable energy capacity. It can serve as a fuel in stationary systems for buildings, backup power, distributed generation, or for high-temperature industrial heat. As discussed, hydrogen could become a key sustainable energy carrier in mobility applications – whether by powering fuel-cell electric vehicles such as hydrogen cars, trucks, and trains or as a feedstock for synthetic fuels for ships and planes. It can also complement ongoing efforts to electrify road and rail transportation and provide a scalable option to decarbonize the shipping and aviation segments.

[9] Hydrogen Council and McKinsey, *Hydrogen Insights*, 2023.

Fig. 5.4 - Hydrogen momentum





Source: Hydrogen Insights (2023)

Hydrogen-powered vehicles offer key advantages, including shorter refueling times, longer ranges, and a lower material footprint than lithium battery-powered electric vehicles. However, high total costs of ownership and lack of enabling infrastructure are key challenges. Therefore, realizing the promise of hydrogen as a sustainable mobility energy carrier will require robust policy support, technological innovation, and committed investment.

Technology Focus -Hydrogen Fuel Cells and Electrolysis

Fuel cells convert hydrogen-rich fuels into electricity through a chemical reaction, with water and heat as the only by-products. A fuel cell consists of an anode, a cathode, and an electrolyte membrane. The stored hydrogen passes through the anode, where it is split into electrons and protons. Electrons pass through an external circuit, generating electric power, which can be fed directly to a vehicle's electric motor or stored in batteries. Protons pass through the membrane to reach the cathode, combining electrons and oxygen to produce water molecules.

Fuel cells offer a unique and wide range of potential applications: they can power systems as small as a laptop computer or as large as a utility power station. They can also replace internal combustion engines (ICE) in mobility applications. FCEVs use a fuel cell, rather than a battery, to power electric motors. FCEVs are a zero-emissions alternative to conventional ICE and BEVs, which use lithium-ion batteries to store electrical energy produced outside the vehicle. Hydrogen FCEVs operate near-silently since they have no moving parts and produce no tailpipe emissions. However, while clean-burning by itself, as discussed, hydrogen must be produced from renewable or nuclear energy to harness its full environmental benefits.

Electrolysis refers to the production of hydrogen and oxygen using electricity to split water, which can be thought of as the reverse process of a fuel cell. The reaction occurs within an electrolyzer unit, which can range from small appliance-sized equipment well-suited for distributed hydrogen production to large-scale, central production facilities connected directly to renewable or other zero-carbon electricity sources. Like fuel cells, electrolyzers consist of an anode and a cathode separated by an electrolyte membrane.[10]

Road Transportation

Road vehicles account for about 74% of transportation-specific emissions (Figure 5.2). In 2022, private cars and vans were responsible for more than 25% of global oil use and around 10% of global energy-related CO_2 emissions. Efforts to decarbonize the sector have thus far focused mainly on electrification (BEVs), accompanied by technologies to improve the fuel economy of ICEs. However, the rise of heavier and less efficient vehicles like SUVs continues to slow progress. Yet hydrogen-powered FCEVs offer substantial promise.

FCEVs have significant advantages over BEVs in terms of refueling times and driving ranges. Refueling times are much shorter; filling current models takes between three and five minutes and closely resembles the experience with a conventional vehicle.[11,12] In contrast, recharging a BEV can take anywhere from 20 minutes to 12 hours, depending on the battery size, charger capacity, and depth of charge.[13] Driving ranges vary but tend to be similar to those of conventional vehicles (400-600 km).[12,14] Fuel cells also provide higher energy

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[10] N. De Blasio and F. Pflugmann, "Is China's Hydrogen Economy Coming? A Game-Changing Opportunity", Harvard University, Belfer Center for Science and International Affairs, 2020.

[11] California Air Resources Board, "Hydrogen Fueling", 2024.

[12] Department of Energy (DOE), "Alternative Fuels Data Center – Hydrogen Basics", 2020.

[13] US Environmental Protection Agency (EPA), "Green Vehicles Charging", 2024.

[14] J. Kurtz, S. Sprik et al., "Fuel Cell Electric Vehicle Driving and Fueling

densities, lower weights, and a lower material footprint than lithium batteries.[15,16] Given these benefits, FCEVs are ideally suited for end users who require low downtimes, drive long distances, and carry heavy loads, such as taxis, buses, trucks, and heavy-duty vehicles.[17]

However, widespread adoption of FCEVs is more challenging than it might seem; otherwise, they would dominate battery-powered and conventional vehicles globally. Significant issues hindering deployment at scale need to be addressed.

First, fuel cells are more expensive than comparable-sized light-duty conventional vehicles, even if leasing packages often include fuel, service, and maintenance, making the total costs of ownership relatively similar. For heavy-duty trucks, analysts foresee that hydrogen could become competitive with diesel by 2030.[18]

Second, the lack of enabling infrastructure remains a key barrier. Although hydrogen refueling infrastructure deployment continues to accelerate in China and South Korea, only about 1,100 hydrogen refueling stations are operational globally,[9] compared to over 2.7 million public charging points worldwide.[19] Building a hydrogen fueling station currently costs between $1.5 and $2 million,[20] while an ultra-fast-charging electric vehicle station with a single 150 to 350 kW charger can cost between $85,000 and $250,000.[21] These investments are

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Behavior", National Renewable Energy Laboratory (NREL), 2019.

[15] The Fuel Cell and Hydrogen Energy Association, "Roadmap to a US Hydrogen Economy", 2020.

[16] Department of Energy (DOE) (2024) "Fuel Cell Vehicles"

[17] J. Jones, A. Genovese, and A. Tob-Ogu, "Hydrogen vehicles in urban logistics: A total cost of ownership analysis and some policy implications", *Renew Sustain Energy Rev*, vol. 119, 2020.

[18] S&P Global, "Hydrogen fuel cells to compete with diesel truck engines by 2030", 2021.

[19] International Energy Agency (IEA) "Global EV Outlook 2023", 2023.

[20] Department of Energy (DOE), "Hydrogen Fueling Stations Cost", 2021.

[21] McKinsey Center for Future Mobility, "Can public EV-fast charging stations be profitable in the United States?", 2023.

significant, particularly with very few vehicles operating, yet a lack of refueling infrastructure is often cited as the key obstacle to the widespread adoption of FCEVs. Regardless, stakeholders around the globe are increasingly recognizing hydrogen's promise for the sector. Unsurprisingly, the sales of FCEVs correlate geographically with the deployment of hydrogen refueling infrastructure. South Korea leads in the light-duty sector (about 50% of the current fleet), while China leads in the global heavy-duty truck and bus markets with about 80% and 90%, respectively.

From a value chain perspective, FCEVs will complement, rather than compete with, BEVs. They will be key in the decarbonization of heavy-duty, long-distance applications, starting with captive fleets that require quick refueling and high uptimes. Government support and public-private partnerships will be key to accelerating innovation cycles and the deployment of enabling infrastructure at scale.

Next Stop - Hydrogen Trains

Rail is one of the most energy-efficient and clean transport modes. Trains carry about 7% of global motorized passengers and 6% of freight while accounting for about 1% of the overall transportation sector's CO_2 emissions. As a reference, on a well-to-wheels basis,[22] rail emissions per passenger average around one-fifth of those of air travel.[23]

As old diesel trains are phased out of rail networks, hydrogen could become the answer to the sector's complete decarbonization. Compared to other low-carbon alternatives, such as electric trains, hydrogen offers greater flexibility and affordability, particularly over long distances and in rural areas.

[22] Well-to-wheel emissions refer to all fuel production, processing, distribution, and use emissions. Using gasoline as an example, emissions are produced during oil extraction, refining, distribution to gasoline stations, and burning in vehicles.
[23] International Energy Agency (IEA), "Transport – Rail", 2024.

Decarbonizing rail systems remains difficult, nevertheless. In many countries, diesel trains still dominate. In 2021, among EU-27 countries,[24] nearly 44 % of rail lines were still diesel-powered,[25] compared to the near totality of freight and passenger rail locomotives in the US.[26] So far, electrification has been the preferred decarbonization option, but interest in hydrogen alternatives is rising. Hydrogen-powered trains have been in service in Germany since 2018, and pilot tests have been completed in Austria, the Netherlands, and Sweden.[27] In 2023, France ordered twelve hydrogen trains to begin commercial operations by 2025,[28] and Italy allocated €300 million to new hydrogen trains and associated green hydrogen projects.[29] In February 2024, California announced a $127 million investment to double its hydrogen-powered passenger train fleet.[30] It is important to note that while, so far, advanced economies have driven most hydrogen rail projects, developing economies have also recently started to invest. Notably, India has announced a pilot project to produce hydrogen trains in Chennai.[31]

Cost is a key motivation for adoption. Hydrogen trains reduce emissions at a significantly lower cost than track electrification. While a new Alstom hydrogen-powered train can cost up to

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[24] Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

[25] Statista Research Department "Share of the rail network which was electrified in Europe by 2021, by country", 2024.

[26] Department of Energy (DOE), "The U.S. National Blueprint for Transportation Decarbonization", 2023.

[27] Alstom, "Alstom's Coradia iLint hydrogen train runs for the first time in France", 2022.

[28] SNCF Group, "The First Hydrogen Trains to Circulate in 2025", 2023.

[29] "Italy allocates €300m to new hydrogen trains and associated green H2 projects", *Hydrogen Insight*, 2023.

[30] "California Continues to Expand Hydrogen-Powered Passenger Rail Fleet", *Caltrans*, 2024.

[31] "Indian Railways' Hydrogen-Powered Train Project", *Financial Express*, 2024.

$11 million,[32] an analysis of twenty railway lines in the UK and mainland Europe showed that the electrification of a single kilometer of track could cost upwards of $1 million.[33] Even if hydrogen locomotives require their own refueling and servicing infrastructure, costs will likely remain competitive because there is no need for track overhauls. This makes hydrogen trains particularly valuable in rural areas, where fewer passengers tend to travel longer distances.[34]

Another significant advantage of hydrogen-powered alternatives is their potential to serve as bi-mode trains, running on both electrified and conventional lines. This option makes hydrogen trains a flexible alternative for decarbonizing the sector, while most tracks are not yet electrified. In addition, hydrogen trains are more resilient to network-wide disruptions, as a shared electric infrastructure means that any damage would impact all electric trains running on a given line. A hydrogen train could simply switch to its fuel cell to produce electricity. Yet, hydrogen rail systems have challenges.

Deploying the required infrastructure and hydrogen's lower volumetric energy density than diesel pose substantial barriers. Since freight is heavier than passenger transportation, hydrogen trains will require more fuel than diesel trains to serve the same routes. Therefore, innovation in more efficient ways to compress and store hydrogen will be needed to improve economics and scalability.

Shipping

Despite being one of the most efficient forms of freight transport, shipping remains a challenge for decarbonization

[32] Alstom, "Alstom to supply Italy's first hydrogen trains", Press Release, 2020.

[33] Railway Industry Association, "RIA Electrification Cost Challenge", 2019.

[34] F. Zenith, R. Isaac, A. Hoffrichter, M. Thomassen, and S. Møller-Holst, "Techno-economic analysis of freight railway electrification by overhead line, hydrogen and batteries", *J Rail and Rapid Transit*, vol. 234, no. 7, 2020, pp. 791-802.

efforts. In 2022, the sector accounted for about 2% of global and about 11% of transportation-related CO_2 emissions, and it has in place a revised (now in line with the Paris Agreement) self-imposed goal of reducing emissions by 40% by 2030 from 2008 levels and be net-zero by 2050.[35]

Thus far, electrification has been the preferred decarbonization option. Battery-operated ships are already replacing vessels running on marine diesel oil (MDO) for short-distance operations like ferries.[36] But complete electrification remains a problematic value proposition due to the volume cargo operators would lose to store enough energy for long-distance shipping. Large ships crossing oceans would simply need too many batteries. Hence, low-carbon fuels with high energy densities, such as hydrogen and ammonia, are expected to play a key role in the industry moving forward. On an energy content parity, while batteries require 64 times more volume than MDO, hydrogen and ammonia only need 8 and 3 times more, respectively.[37]

Ammonia, a hydrogen-based molecule, is a fuel that can either be combusted in an engine or used in a fuel cell. Liquid ammonia not only packs twice as much energy per volume as hydrogen but is also far easier to store because it needs simple refrigeration (-35°C) and not the cryogenic temperatures of hydrogen (-253°C). Furthermore, ammonia could be converted back to hydrogen directly onboard, allowing operators to load and store ammonia but ultimately use it in a hydrogen fuel cell. However, ammonia is toxic to both humans and marine life; hence, safety and environmental hazards need careful evaluation and consideration.

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[35] International Maritime Organization, "2023 IMO Strategy on Reduction of GHG Emissions from Ships", 2023.

[36] Bastø Fosen, "The world's largest electric car ferry on the Oslo Fjord", 2021.

[37] Amplifier, ETH Zürich, SUS Lab Sustainability in Business Lab, "Towards Net- Zero: Innovating for a Carbon-free Future of Shipping in the North and Baltic Sea. DEEP-DIVE: Comparison of zero-carbon fuels", October 2019.

Costs are critical as hydrogen-based fuels are still more expensive than conventional ones. Due to the added conversion steps, costs are even more significant in the case of ammonia. Although orders for new ships are starting to show a trend toward alternative fuels – in 2022, 90 (11% by tonnage) new-build orders were for ammonia-ready vessels, and three for hydrogen-ready vessels.[38] Robust global hydrogen and ammonia networks to ensure that ships can refuel at any port will be key for the sector's transition to a low-carbon economy. Policymakers must support innovation, deployment of enabling infrastructure, and the definition of appropriate safety standards and regulations.

To date, over 160 companies have joined forces in the Getting to Zero Coalition, which aims to achieve commercially viable zero-emission shipping by 2030 and full decarbonization by 2050.[39] According to the International Council on Clean Transportation, liquid hydrogen could fuel up to 99% of existing interoceanic routes between China and the United States with the addition of a single refueling stop.[40] As of 2022, more than 203 zero-emission shipping pilot projects had been demonstrated worldwide, up from 106 and 66 in 2021 and 2020, respectively.[41]

Hydrogen Powered Skies

As international travel demand recovers after the Covid-19 pandemic, aviation emissions reached about 80% of their pre-pandemic peak. In 2022, aviation accounted for 2% of global energy-related CO_2 emissions and 11% of transportation-related CO_2 emissions. However, these seemingly small numbers

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[38] Clarkson Research (2023) "Green Technology Tracker: January 2023."

[39] International Maritime Forum (2024) "Getting to Zero Coalition."

[40] The International Council on Clean Transportation, "Liquid Hydrogen Refueling Infrastructure to Support a Zero-Emission U.S.–China Container Shipping Corridor", 2021.

[41] Global Maritime Forum, "Mapping of zero-emission pilots and demonstration projects", 2022.

should not be dismissed since the sector's overall contribution to global warming is significantly higher due to emissions other than CO_2, like nitrogen oxides and soot. The sector needs scalable decarbonization pathways to reach net-zero emissions by 2050 in an environmentally and economically sustainable manner. Efficiency improvements have not been able to keep up with demand, which grew at an average rate of over 5% annually between 2010 and 2019. Sustainable aviation fuels (SAF), including hydrogen, are poised to play a key role in this transition. Currently, though, jet kerosene dominates fuel demand, while SAFs account for less than 0.1%.[42]

The advantages of hydrogen as an aviation fuel have been well-known for decades. Thanks to an energy density by mass three times higher than traditional jet fuel, liquid hydrogen has been the signature fuel for the American space program since the late 1950s. As a more scalable alternative to battery-powered aviation concepts, which present significant challenges, especially for larger aircraft applications due to energy density and safety considerations, hydrogen is now emerging as a significant component of commercial flights' future technology mix. Hydrogen can be used via direct combustion in jet engines or in fuel cells to generate electricity for electric motors or a combination of the two.

However, the road to hydrogen-powered aircrafts remains to be determined, and significant efforts will undoubtedly be required by all stakeholders to further invest in enabling technologies and overall value chains. From an innovation perspective, the aviation industry will need to borrow technologies developed for the automotive and space sectors and apply them to commercial aircraft operations, notably by reducing weight and costs. One specific challenge will be how and where to store hydrogen onboard aircrafts while achieving similar or better safety targets than existing ones. Beyond the technical aspects, this will require hydrogen-specific safety

[42] International Energy Agency (IEA), "Transport – Aviation", 2024.

and regulatory standards that currently do not exist. Adopting hydrogen at scale will also hinge on robust hydrogen-fueling infrastructure networks. While this challenge is daunting due to the high fuel demand associated with airport operations, hydrogen could also be produced directly onsite, eliminating distribution costs.

In 2023, the first test flights using fuel cell-powered electric motors took place. ZeroAvia flew a 19-seat aircraft with a hydrogen-electric engine on its left wing,[43] while Universal Hydrogen flew a 40-seat regional airliner with a fuel cell powering one of the engines.[44] In parallel, assessments of alternative propulsion systems have been conducted. Rolls-Royce and easyJet have performed a ground test combusting green hydrogen in a regional jet engine.[45] Airbus has also designed and produced the first cryogenic liquid hydrogen tank prototype.[46]

From a policy perspective, greater incentives for low-carbon aviation fuels, support for developing and deploying enabling technologies and infrastructure, and harmonizing safety standards and regulations will be key to decarbonizing aviation. Yet, due to very long aircraft development and certification lead times, these challenges demand urgent answers from industry leaders and policymakers, who must keep up to date on the opportunities and barriers facing hydrogen-powered aviation, including public perception concerns.

[43] ZeroAvia, "ZeroAvia Makes Aviation History, Flying World's Largest Aircraft Powered with a Hydrogen-Electric Engine", 2023.

[44] Universal Hydrogen, "Universal Hydrogen Successfully Completes First Flight of Hydrogen Regional Airliner", 2023.

[45] Rolls-Royce, "Rolls-Royce and easyJet set new world first", 2022

[46] Airbus, "The cold heart that powers our ZEROe aircraft", 2022.

Conclusion

Hydrogen must overcome significant barriers, mainly related to storage, infrastructure, and costs, before becoming a game changer in transportation.

In road transportation, competitiveness will depend on overall costs of ownership and availability of refueling infrastructure. Key advantages include short refueling times, lower added weight for stored energy, and zero tailpipe emissions. Fuel cells also show promise thanks to their lower material footprint than lithium batteries. Long-distance and heavy-duty segments offer the greatest potential, but investments are required to lower the delivered price of hydrogen. Captive fleets can help to overcome the challenges of low utilization of refueling stations and spearhead the adoption of hydrogen.

In the rail sector, hydrogen trains could be most competitive in rail freight and rural/regional lines where long distances and low network utilization do not justify the high costs associated with track electrification. Hydrogen trains also hold promise due to flexible bi-mode operations.

Shipping and aviation have limited low-carbon fuel options, representing a significant opportunity for hydrogen-based fuels. In maritime applications, hydrogen and ammonia can overcome the limitations of battery ships and provide a route for meeting national environmental ambitions and the sector's emission reduction targets. However, high costs compared to fossil fuels, the challenge of cargo volume loss due to fuel storage, and the deployment of global refueling networks need to be addressed.

In the aviation sector, drop-in synthetic liquid fuels provide an attractive decarbonization option at the expense of higher energy consumption and costs. Direct hydrogen use also shows promise. However, the sector will need to borrow technologies developed for the automotive and space industries and apply them to commercial aircraft operations while achieving similar or better safety targets.

Innovation will be crucial to reducing costs and improving the performance of electrolyzers, fuel cells, and hydrogen-based fuels. Progress is needed to address technological challenges around weight and hydrogen storage, particularly in the maritime and aviation sectors.

From a policy perspective, adoption at scale will require to:

- Establish a role for hydrogen in long-term domestic and international energy strategies, considering geopolitical and market implications.
- Implement policy support through low-carbon targets and carbon pricing measures to stimulate commercial demand for clean hydrogen.
- Address investment risks, especially for first movers, such as targeted and time-limited loans and guarantees.
- Focus on new hydrogen applications, clean hydrogen supply, and infrastructure projects.
- Support research and development efforts and public-private partnerships to accelerate innovation cycles.
- Harmonize standards and eliminate unnecessary regulatory barriers while developing certification systems and regulations for carbon-free hydrogen supply.

To date, technological factors, economic considerations, and consumer choices have hindered the adoption of hydrogen at scale in the transportation sector. New geopolitical forces – such as the challenges of sustainable development and climate change – are reshaping the playing field. Stakeholders around the world will need to decide their role in this transition.

6. Technology, Artificial Intelligence (AI) and Digital: Backbone of the New Logistics?

Nicola Sandri, Stefano Napoletano, Luca Milani, Andrea Ricotti

Geopolitics and the Geometry of Global Trade

The McKinsey Global Institute's recent report "Geopolitics and the geometry of global trade"[1] looks at shifting global trade flows and considers potential reconfigurations based on developing economies and geopolitical distance. The report yields five key messages regarding the future evolution of global trade flows:

- **Trade in concentrated products binds geopolitically distant economies**. Trade between geopolitically distant economies accounts for nearly 20% of global goods trade but close to 40% of trade in globally concentrated products – products such as laptops and iron ore, for which three or fewer economies provide at least 90% of global exports.
- **Trade reconfiguration is under way**. Since 2017, China, Germany, the United Kingdom and the United States have reduced the geopolitical distance of their trade by 4% to 10% each. The United States has

[1] January 2024.

also reduced the geographic distance and diversified the origins of its trade. Meanwhile, economies of the Association of Southeast Asian Nations, Brazil and India are trading more both across the geopolitical spectrum and over longer distances.

- **Increased investment into a range of developing economies suggests further trade reconfiguration in coming years**. While roughly 60% of greenfield investment has flowed to developing economies since 2010, its destination is shifting. The largest leaps in the past two years were in Africa and India, while announced investment into China and Russia fell by about 70% and 98% respectively, compared with pre-pandemic averages.
- **The future of global trade will involve trade-offs – reducing geopolitical distance comes with increasing trade concentration, and vice versa**. There are two types of reconfigurations. In one, economies shift their trade to more geopolitically aligned partners. As a byproduct, average trade concentration increases by 13% and economic growth suffers. In the other, trade relationships diversify so that no economy is highly dependent on another, but as a consequence, the geopolitical distance of trade increases by 3%. The degree of trade-off varies significantly across individual economies.
- **Business leaders need to position their organizations for uncertainty**. This positioning can involve cultivating an insights edge, anticipating and adapting with scenario planning, developing a portfolio of strategic actions, and building geopolitical muscle. Businesses can also embrace cooperation to contribute to, and help shape, the discourse on the evolution of global connections.

The changing environment described above highlights the fact that businesses will need to plan for disruptions, and two recent examples in shipping show just how great the need is. Firstly, the cost and delay implications of low water levels in the Panama Canal, which normally carries around 8% of global container volume, have been visible. Extreme drought has reduced maximum ship crossings, resulting in prolonged waiting times. Consequently, several carriers have already announced new fees for Panama transits. In addition to costs incurred by shipping companies and their clients, costs for the Panama Canal itself are now expected to rise to between $500 million and $700 million in 2024, compared with previous forecasts of $200 million.

At the same time, conflict in the Red Sea and reduced access to the Suez Canal are leading companies to reroute shipping around the Cape of Good Hope, adding about two weeks to shipping time while raising costs for resources such as fuel for the vessel and food for the crew. While this delay is relatively short if a supply chain is prepared accordingly, there have been reports of automotive companies implementing line stoppages in response to material shortages. The direct impact on business revenue illustrates the need to invest in resilient supply chains.

These are just two cases calling for measures to increase supply chain resilience, as waiting for that normalization to happen is not an attractive option. The expectation of more frequent disruptions suggests a need to prepare for the future. Supply chain leaders can prepare by developing an understanding of their operations and the world in which they are operating. Firstly, they should establish an insights edge for competitive advantage, with a granular view of their company, peers and other elements of the value chain, and the broader global context. Secondly, it is important that supply chain leaders understand their tier-n connections in detail. Indeed, McKinsey Global Institute's research shows that only 2% of companies have visibility below tier two. And finally, it is becoming increasingly important for leaders to monitor the world for tremors that may signal challenges to their operations; looking solely at their own value chains will no longer be sufficient.

Companies operating in the global logistics and supply chain industries have clearly been impacted more than others. Indeed, logistics and shipping operators continue to face challenges in their operating environment: according to the latest McKinsey Logistics Survey,[2] cost management, driver management and productivity improvement were the top three pain points reported in the transport phase of the logistics value chain. In warehousing, survey respondents identified labor management, productivity improvement, and performance management as the most pressing issues. Consequently, logistics companies are turning to new digital innovations, Artificial Intelligence (AI) solutions and technological developments to transform global logistics chains to ultimately reduce costs and improve productivity.

The Role of Digital, Artificial Intelligence (AI) and Technologies in Transforming Global Logistics Chains

According to the latest McKinsey Logistics Survey,[3] logistics operators have grown their investments in digital logistics since 2020, across all technologies: 87% of shippers reported maintaining or growing their technology investments since 2020 and 93% said they plan to maintain or increase their spending over the next three years.

Tech-enabled uses are shaping and impacting the future of logistics, across all the phases, with particular attention to transportation, warehousing, and planning. Whereas some applications are already at an advanced stage of development and widely adopted by companies worldwide, others are still in the early stages of development with full rate adoption yet to be achieved in the coming months and years. The paragraphs

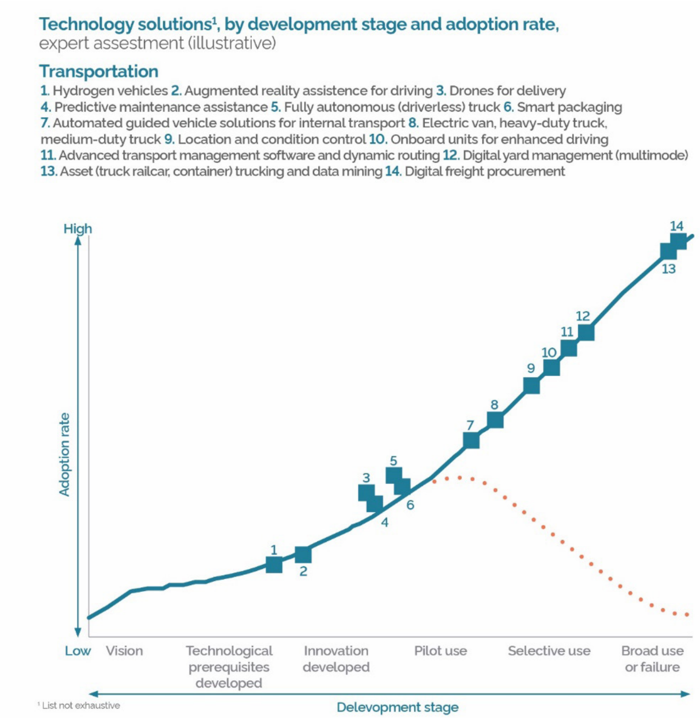
[2] Survey conducted on 258 respondents (220 shippers, 38 providers), between 5-20 May 2023.

[3] Quoted in the McKinsey's article "Digital logistics: Technology race gathers momentum", November 2023.

that follow classify the different tech-enabled use cases in the transportation, warehousing and planning phases by development stage and adoption rate.

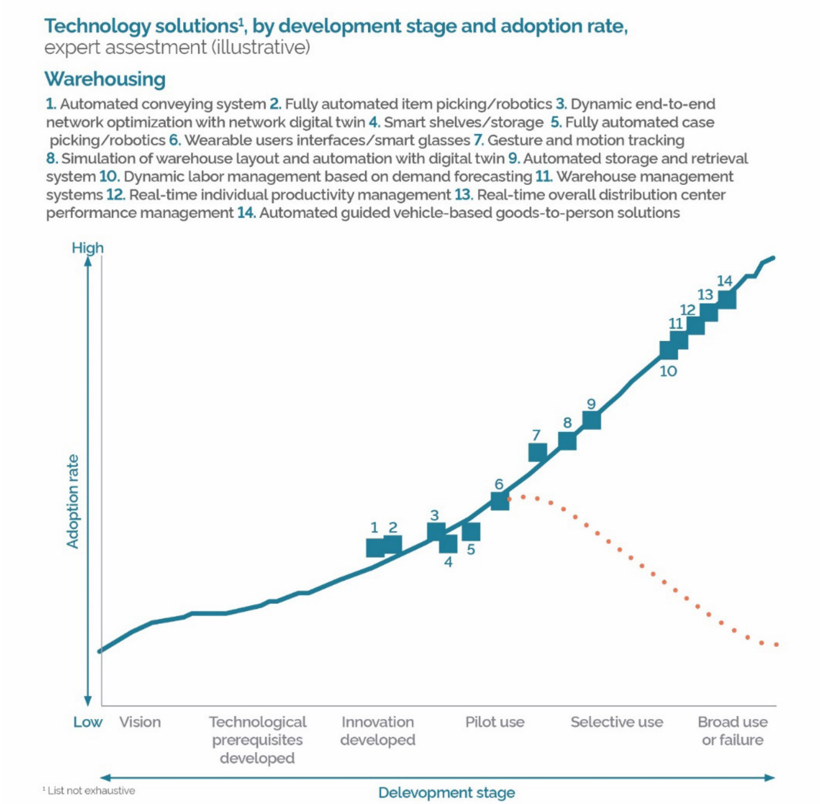
Firstly, as far as the transportation phase is concerned, digital freight procurement (#14) and asset tracking and data mining (#13) are in broad use. Automated guided vehicles (AGVs) for internal transport (#7), enhanced driving solutions (#10), and digital yard management (#12) are starting to scale up. Cutting-edge technologies, such as delivery drones (#3) and hydrogen vehicles (#1), are at much earlier stages of development.

FIG. 6.1A – TECH-ENABLED USE CASES ARE CHANGING THE FUTURE OF LOGISTICS, BUT THEY ARE AT VARIOUS STAGES ON THE INNOVATION CURVE - TRANSPORTATION



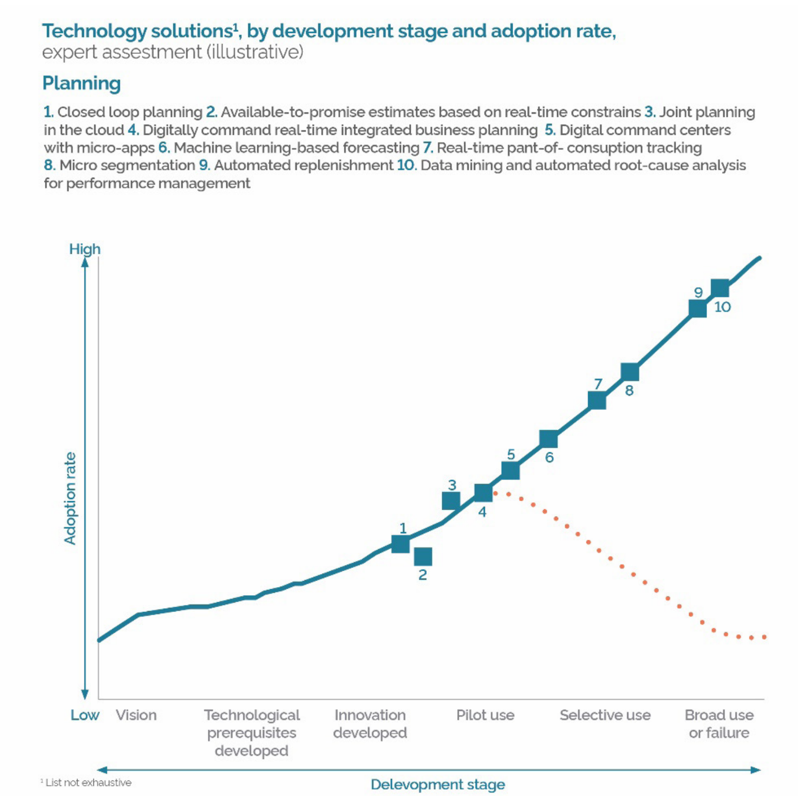
Secondly, in the warehousing phase, some applications, such as real-time distribution center performance management (#13), AGV-based goods-to-person solutions (#14), and warehouse management systems (#11), are already in (or nearing) broad use. Digital warehouse twins (#8), dynamic labor management (#10), and gesture and motion tracking (#7) have proven themselves in piloting, while fully automated item picking (#2), network digital twins (#3), and smart shelves (#4) are demonstrating feasibility.

Fig. 6.1b - Tech-enabled use cases are changing the future of logistics, but they are at various stages on the innovation curve - Warehousing



Finally, in the planning process, technologies in wide use include automated replenishment (#9) and data mining and automated root-cause analysis for performance management (#10). Machine learning-based forecasting (#6) and micro-segmentation (#8) are now in selective use. Digital command centers with micro-apps (#5), which are moving out of the pilot stage, enable oversight of the entire logistics system: transportation, warehousing, and planning, all in one place.

Fig. 6.1c – Tech-enabled use cases are changing the future of logistics, but they are at various stages on the innovation curve - Planning



Expanding digital logistics capabilities can generate significant value with regards to cost and service delivery, boosting operational performance, sustainability, customer satisfaction, and revenue in some cases. On the operations side, digital tools can optimize logistics across planning, execution, and settlement: leading logistics players are already seeing performance improvements of 10% to 20% in the short term, and 20% to 40% within two to four years. In addition, by integrating resilience into core business decision-making through digital logistics tools, businesses can de-risk their EBITDA by up to 60% and boost company valuations by up to 20%, as customers increasingly show a preference for companies boasting green-shipping credentials and stable service levels.

To get ahead in the digital logistics race, and given the potential benefits that digital applications can provide, companies need to understand not only where to invest but also how to transform their operating models through a multipronged approach that encompasses the following:

- Creating a vision of the future state, including the from-to transformations needed in processes, systems, and capabilities.
- Building capabilities to scale and sustaining specific use cases across business units.
- Developing change management programs and defining new ways of working to achieve a high-performing organization.
- Getting the right systems and data infrastructure in place to support new technology.
- Adapting processes with an eye toward value to ensure chosen solutions are sustainable and scalable.
- Measuring regularly and adapting early, with real-time performance management and decision-making support.
- Conducting proof of concept sprints to iterate and learn.

Generative AI: Deep Dive on Economic Potential in Logistics

Generative Artificial Intelligence (gen-AI) has arguably been one of the hottest topics of 2023 in the business world. According to a recent report by McKinsey[4], more than 25% of over 1,100 C-suite executives surveyed admit that AI and gen-AI are at the top of their boards' agendas and 40% of respondents say their organizations will significantly increase their investment in AI in the months to come.

The reason for this steep increase in the level of interest in Artificial Intelligence lies in the new capabilities introduced by Large Language Models, the technology behind what we usually call "gen-AI". While Traditional AI is typically focused on data analysis, and can therefore solve analytical tasks faster and more efficiently than humans and classify, cluster, evaluate and predict data, Large Language Models introduce "human-like" capabilities to create new content and interpret any form of information (whether text, code, video or audio).

The value at stake is massive. McKinsey estimates[5] that Artificial Intelligence could unlock additional potential value of $17-26 trillion, of which $2.6-4.4 trillion could be generated by gen-AI applications across different industries and functional domains.

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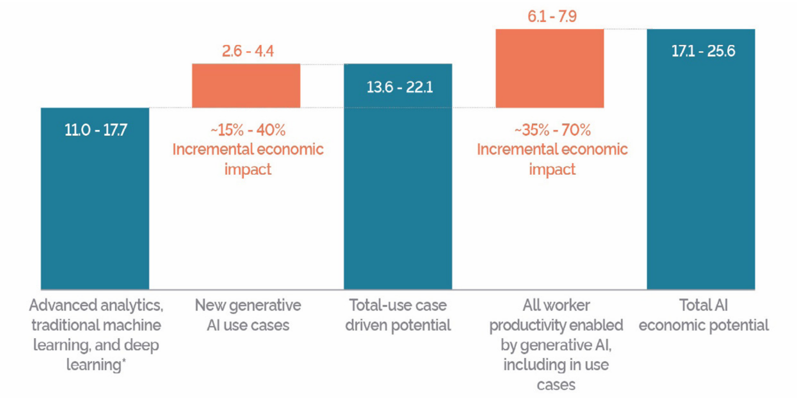
[4] "The State of AI in 2023", McKinsey, August 2023.

[5] "The economic potential of generative AI", McKinsey, June 2023.

Fig. 6.2 - Generative AI could create additional value potential above what could be unlocked by other AI and analytics



*Notes from the AI frontier: Applications and value of deep learning

Supply chains and logistics sectors are not excluded, with growing emergence of specific use cases, across the whole supply chain:

- **Sales**: the most interesting use cases in this phase concern:
  - Next-generation customer reach and conversion, used to send hyper-personalized messages through the channel of choice, and dynamically enrich lead data by prioritizing on the basis of complex sets of factors (e.g., past written messages).
  - Automated generation of cargo documentation, used to generate the necessary documents for transportation (e.g., Bill of Lading) and answer agent and/or customer enquiries based on Gen-AI classification models.
  - Automated booking management, in the form of chatbots that enable customers to rapidly book capacity for shipments based on information entered as text in a chat.

- **Transport planning**: the most interesting uses cases in this phase relate to:
  - Logistics network and scheduled simulation, aiming at increasing the speed and parameters used in simulations when designing and optimizing logistics network (e.g., routes, schedules, disruption on routes).
  - Trade regulation e-advisor, leveraging a Gen-AI agent to monitor relevant regulations/policies and issue alerts in the event of material changes that could impact customers or operations, thanks to semantic queries.
- **Transport management**: the most interesting uses case in this phase relate to transport exception management and involve the use of chatbots to retrieve shipment information for customers instantly (e.g., ETA, disruptions, status, location).
- **Customer support**: the most attractive use cases in this phase concern:
  - Automated invoicing, involving the use of a Gen-AI agent to retrieve pre-filled invoices based on available transaction data and adjustments from unstructured data (e.g., comparison with contract, adjustments in fares).
  - Customer request management, involving the generation of suggested responses to customer queries regarding future or ongoing transport (positioning, condition checks, etc.) and/or making information readily available via customer portals.
  - Tailored return offers/claims management, based on analyzing individual customers' behavior and the wider context (e.g., customer size, original negotiation, demand, cost, return time).
- **Storage**: the most interesting uses case in this phase include automated warehouse operations, based on leveraging Gen-AI to augment the automation of

warehouse and inventory management by means of robots that visually inspect shelf inventory for defects and optimize order management.

- **Asset management**: the most attractive use cases in this phase include next-gen digital maintenance guides, in the form of interactive guides that provide live instructions to maintenance crews, based on capabilities such as advanced image recognition.

The above-mentioned Gen-AI use cases could yield significant benefits for logistics players. Firstly, in terms of aspirational values and potential outcomes, sending hyper-personalized messages through the channel of choice and providing real-time negotiating prompts driven by past-success data points can increase revenues by 3-15% from new customers, increase pipeline velocity by 20% and achieve a 50% reduction in cost per lead.

Secondly, automated cargo generation can cut the time taken to produce transport documentation by 60% and involves 5-8 times less manual work in the Bill of Lading process. Moreover, the use of chatbots to retrieve shipment information for customers instantly (e.g., ETA, disruptions) can lead to a 4-5% bottom-line uplift potential and 13-18% reduction in time spent by staff on handling exceptions.

Lastly, generating automatic responses to customer queries regarding ongoing transport and making information readily available via customer portals can increase customer satisfaction by 20%, decrease the customer attrition rate by 25% and reduce administrative lead times by 20%.

Deep Dive on Digital and Tech Applications in Ports

As highlighted in the introduction, recent disruptions to global supply chains call for measures to increase supply chain resilience and ensure that global trade is not negatively impacted by external shocks. In this context, transport infrastructures, both domestic and international, are critical enablers of smooth freight flows between regions. Ports in particular are essential to global logistics flows because they serve as key transportation hubs for the movement of goods and materials between countries, thus playing a crucial role in facilitating international trade and connecting different regions of the world. In addition, port inefficiencies can have significant financial and operational impacts on the shipping industry, highlighting the need for continuous improvement and optimization in port operations.

Digital- and data-enabled interventions can act as critical enablers to achieve these goals in port operations. Implementing these solutions at scale in ports can also be more efficient than in other transport infrastructures, because of the more concentrated nature and footprint of ports (compared with road and rail, for example, which are spread over wider geographical areas).

Examples of digital applications in port operations include:

- Tools to estimate the time of arrival of ships & cargo availability to optimize turnaround activity (incoming journey, tugs, pilots), optimize berth planning, optimize container moves and remove redundant journeys by matching import-export empty containers.
- Use of port performance indicators to inform the wider audience of ports' stakeholders and optimize ecosystem utilization by providing container information to all parties.
- E-documentation for bills of lading, pilot documentation, and transport instructions.
- AI-driven asset management to optimize asset availability and maintenance.
- The paragraphs that follow take an in-depth look at the tools available for estimating the time of arrival of ships & cargo availability and the use of port performance indicators, given the potential impact these applications have on port operations, in terms of both costs and revenues.

Estimated Time of Arrival of Ships (ETA) & Cargo Availability

This system of estimated time of arrival of ships & cargo availability is designed to increase information flows within and outside ports and plays a major role in reducing waste along the container value chain. The process works as follows:

- On the "sea" side, multiple sources provide information such as vessel position and cargo destination, which is stored in a data utility; the data utility provides data to a solution developer through an API; the solution developer calculates the exact estimated time of arrival, which is eventually provided to all members of the port community, thus enabling them to organize and deploy port operations efficiently.
- On the "terminal and hinterland side", data on container status (e.g., unloading timing, customs clearing process) is provided to the data utility, which collects and transfers the information to the solutions developer, who creates an application to provide container status. Eventually, port stakeholders can access the status of the container online (or by alert) to smooth container movement.

7. Case Studies

7.1. SEA: Could the Airports Be Responsible for the Environment?

Massimo Corradi, Paolo Dallanoce

Milan Malpensa Cargo is the national hub for import and export air cargo distribution. Thanks to its specialized infrastructure, it is the number one cargo airport in Italy, accounting for more than 60% of domestic traffic, and the fifth largest in Europe (if one does not consider airports focused exclusively on cargo).

In 2023 Malpensa handled more than 670,000 tons of cargo, an increase of about 20% over pre covid (2019) volumes. This volume growth was strongly influenced by the great development of e-commerce, which mainly favored courier carrier traffic but also the all-cargo freighter segment, especially in imports from Asian markets.

Malpensa Cargo City covers an area of about 500,000 square meters, including 100,000 square meters dedicated to frontline warehouses, 250,000 square meters of airside apron with 20 stands for all-cargo aircraft and 150,000 square meters of handling areas for landside trucks.

In order to ensure continuity in the development of the cargo business at Malpensa which benefits the reference territory, SEA Aeroporti di Milano is committed to developing infrastructure capacity in line with growing market demand, with the aim of strengthening and enhancing its role as an airport logistics hub.

In addition to upgrading the physical capacity of the infrastructure dedicated to cargo, SEA is also investing in the efficiency of operational processes, through the promotion and coordination of a series of projects oriented towards sustainability. Particular efforts are being made on the digitization front, necessary to improve processes and increase the efficiency of existing warehouses, through the adoption of operational models and tools integrated with all stakeholders in the supply chain.

The major ongoing digital development projects are as follows:

- The **FENIX** (European Federated Network of Information eXchange in Logistic) Project was launched in 2019 to develop the first European federated architecture for data sharing to serve the European logistics community of shippers, logistics service providers, mobility infrastructure providers, cities and authorities in order to provide interoperability between any existing and future individual platforms. Co-funded by the European Commission through the Connecting Europe Facility (CEF) program and ending in 2023, it was developed over 11 "pilot" activities located in the 9 corridors of the TEN-T network. Two of these pilot activities involve Italy and were coordinated by the Ministry of Infrastructure and Sustainable Mobility, with the support of TTS Italy as project manager, and included the Trieste area and the Italian part of the Rhine-Alps (Lombardy, Liguria and Piedmont). Malpensa Airport in particular has been involved through the integration of the "Smart City of Cargo," the digital ecosystem of the Cargo City of Milan Malpensa, consisting of a series of IT services that enable the transmission and sharing of data related to cargos and their transportation among the actors in the Malpensa cargo supply chain. Within this framework, applications have been developed that allow customs processes and the main air-side and land-side cargo operational processes to be governed and managed digitally. Among these applications is already in production from 2023 the Customs Fast Corridor service, a full-digital service for the transfer of goods under customs import directly to “second-line” warehouses in the territory.

- The **OLGA** (hOListic Green Airport) Project, funded by the European Commission through the Horizon 2020 project program, aims to develop innovative sustainable measures to reduce emissions both on the airstrip and on the ground by improving energy efficiency, air quality, biodiversity and waste management. The consortium, consisting of airports, airlines, ground staff, industry, research centers and SMEs, will work on integrating sustainable aviation fuel supply chains into traditional aviation fuel infrastructure, demonstrating complementary types of low-emission mobility, electric ground handling equipment, hydrogen infrastructures and reduced carbon flight-side operations. In this framework, the following projects are being developed at Malpensa:
  - **SPOT** (**S**mal **P**arcel **O**n **T**rain), which involves the transfer of express parcels between Milan Malpensa Airport and Milan Cadorna Station using the existing “Malpensa Express” rail link. The exploitation of rail-air intermodality allows rapid handling of e-commerce parcels requiring fast delivery, benefiting from reduced environmental impact due to reduced use of road transport. Given the large number of people who regularly travel through Cadorna, the creation of a delivery point at the station makes it possible to deliver parcels not only to the Milan area, through the use of

sustainable means, but also directly to residents of the Lombardy area, who can pick up their orders directly at the station instead of receiving them at their homes.

- **TRUCKPOLING**: The project consists of creating an application to optimize the transport of export goods via truck to Cargo City in Milan Malpensa. Since trucks do not always travel at full capacity, especially for certain types of special commodities (such as pharmaceuticals), the remaining capacity can be shared among operators gravitating to the airport, resulting in a reduction in the number of trucks needed and the associated harmful emissions.

As part of the initiatives to promote the sustainability and safety of heavy road transport at the Malpensa Airport cargo area, the following project is noted:

- The **PASS4CORE** project (Parking Areas implementing Safety and Security FOR (4) CORE network corridors) is a project funded by the CEF-Transport program and aimed at the development and improvement of the national network of safe and secure parking areas for heavy vehicles along the primary road network in Italy. In addition to RAM, which acts as the implementing body of the Ministry of Infrastructure and Transport - Comitato Centrale Albo Autotrasportatori, the project involves 12 beneficiaries including SEA Airports, freeway concessionaires, interports, as well as private operators, engaged in the construction of about 1,350 truck parking lots, upgrading more than 300,000 m^2 on 13 areas dedicated to this purpose and for which the certification of "Safe and Secure Truck Park" will be obtained according to the European standards defined by Esporg, the European Secure Parking Organization. In this context, RAM will be tasked with coordinating the development of such a network of safe and secure parking lots and implementing a digital platform dedicated to managing information about the supply of such stalls for truck drivers. The section of the project in which SEA is engaged is the construction of a secure truck parking facility next to the Cargo City at Milan Malpensa Airport. The infrastructure, which will provide more than 150 truck stalls (of which about 30 feature electric charging) and a building with restrooms and refreshment facilities, will be characterized by high standards of both quality and safety for trucks and drivers.

With reference to initiatives aimed at reducing the impact of CO_2 emissions, SEA Aeroporti di Milano has adhered to the "Net-Zero 2030", by which the airport industry commits to achieve a zero CO_2 emission level by 2030, anticipating the term of the "Net-Zero 2050 resolution" assumed by the European airport industry.

In this context, SEA is coordinating and promoting, with regard to aircraft energy refueling, the implementation in the short term of a supply chain for the procurement, storage, distribution and use of SAF (Sustainable Aviation Fuel) at Malpensa Airport.

On the other hand, with regard to energy supply for airport subsystems (terminals, buildings, and cargo and passenger vehicles), SEA is committed to developing and implementing a hydrogen integration supply chain at Malpensa Airport through the following project:

- **MALPENSA H2**: The project, funded by the PNRR, is being developed by EDISONnext in collaboration with SEA Aeroporti di Milano, near the Malpensa Cargo City area in synergy with OLGA (hOListic Green Airport), a program funded by the European Commission (Horizon 2020) that is part of a broader decarbonization process undertaken by SEA to reduce the environmental impact of the aviation sector. As part of the Malpensa H2 project, Edison Next will build a green hydrogen refueling station, powered by an electrolyzer installed on site, that will supply heavy airport logistics vehicles in the Malpensa Cargo City area. Hydrogen mobility is "zero-emission", meaning that the potentially total replacement of the present fleet of vehicles in the cargo city will enable a major reduction in pollutant emissions from the area. The facility is expected to be in service between December 2025 and February 2026, so that it will be operational for the Milan-Cortina 2026 Winter Olympic Games, which will be held from 6 to 22 February 2026. The green hydrogen refueling station of the Malpensa H2 project will cover an area of about 12,000 square meters and will house cutting-edge technologies and equipment for the production and supply of green hydrogen as well as spaces for services dedicated to the public. The facility will be able to deliver at dual pressures, 350 and 700 bars, in order to service all types of vehicles in the Malpensa Cargo City area. The Malpensa H2 green hydrogen production plant will be built in such a way as to allow for the doubling of its capacity, thus being able to support the development of further steps in the decarbonization path of the airport's vehicle park.

7.2. Ports: An Energy Transition and Decarbonization Master Plan Is Needed

Alexio Picco

Ports play a crucial role in global trade and transportation, but they are also significant sources of carbon emissions. Developing an energy transition and decarbonization Master Plan is an essential step to enable ports to align with sustainability goals and reduce their environmental impact. Such a plan would not only benefit the environment but also contribute to the long-term viability and competitiveness of ports in a changing global landscape. Ports are hubs of economic activity, handling vast amounts of goods and serving as key nodes in supply chains. However, this activity often relies heavily on fossil fuels, leading to high carbon emissions. By transitioning to cleaner energy sources and decarbonizing their operations, ports can significantly reduce their carbon footprint and contribute to global efforts to combat climate change.

The "Master Plan for energy transition and decarbonization" focuses on sustainability education for greener fuels and energy in ports, and covers various domains to drive the transition towards cleaner energy sources. These domains include emphasizing the importance of sustainable energy practices and technologies in the maritime industry, promoting the use of renewable energy sources to reduce carbon emissions and enhance environmental sustainability, encouraging the adoption of renewable energy solutions in port operations to minimise environmental impact, and facilitating the integration of clean energy technologies to achieve greater efficiency and sustainability in port activities.

By focusing on these domains, the Master Plan aims to enhance knowledge, promote best practices, and equip port professionals with the necessary skills to drive sustainable practices and transition towards greener fuels and energy sources within the maritime sector.

Developing a "Master Plan for energy transition and decarbonization" in ports offers a multitude of benefits that extend beyond just environmental impact.

Firstly, imagine a port as a bustling hub of activity, where ships come and go, goods are loaded and unloaded, and operations run round the clock. A master plan acts as a guiding light, illuminating the path towards transitioning to cleaner energy sources systematically. It is like having a detailed map that helps port authorities navigate the complex terrain of sustainability and stay on course towards a greener future.

Secondly, picture a scenario where energy-efficient technologies and practices are seamlessly integrated into port operations. This not only reduces carbon emissions but also leads to significant cost savings and operational efficiency. It is akin to upgrading from an old, inefficient engine to a sleek, high-performance model that not only runs more smoothly but also saves fuel along the way.

Moreover, in today's world, regulations on emissions are becoming increasingly stringent. Having a clear master plan ensures that ports not only meet but exceed environmental standards. It is like having all the necessary paperwork in order before embarking on a journey, so as to ensure smooth sailing without any regulatory hurdles along the route.

Finally, ports that showcase a strong commitment to sustainability attract environmentally conscious partners and customers. Picture a port that shines like a beacon of green practices in a sea of traditional operations. This enhanced reputation not only attracts like-minded collaborators but also sets the port apart as a leader in sustainable maritime practices.

In essence, developing a "Master Plan for energy transition and decarbonization" in ports is akin to charting a new course towards a greener, more sustainable future. It not only aligns ports with global sustainability goals but also positions them as pioneers in the maritime industry, driving positive change and setting new standards for environmental stewardship.

The SEANERGY project (https://seanergyproject.eu/) aims to facilitate the transition of ports towards green energy practices through dialogue, education and technology integration. It is structured in three stages: understanding actors and port systems, developing a Master Plan for energy transition in ports for training stakeholders, and expanding the plan globally. The project involves various participants and focuses on sustainability education for cleaner fuels and energy in ports, contributing to the decarbonization of the sector, through various key strategies and outcomes.

Gap analysis: conducting a thorough analysis of current operations, resources and policies is crucial, in order to identify areas that need improvement. This process helps in understanding the limitations and gaps in preparation that organizations need to overcome in order to actively participate in the transition towards green port operations.

Stakeholder engagement: involving stakeholders from industry, government and academia ensures diverse perspectives are considered in the planning process. This collaborative approach fosters dialogue among all industry agents, and creates spaces for teaching and learning that boost the development and integration of clean energy technologies.

Workshops and surveys: organizing workshops, surveys and co-creation activities plays a vital role in gathering insights and feedback from stakeholders. These activities provide a platform for stakeholders to share their perspectives and contribute to the identification of gaps in knowledge and resources needed for successful green port transformation.

Industry Academy program: establishing training programs focused on clean energy technologies equips port professionals with the skills required for the transition. This program not only educates professionals on the application of clean energy technologies but also ensures they are prepared to manage and implement these technologies efficiently and securely.

Additional outcomes from the SEANERGY Project include integrating innovative technologies like renewable energy systems and smart grid solutions into port operations to enhance sustainability, influencing policy frameworks at local, national and international levels to support the adoption of clean energy practices in ports, and fostering knowledge-sharing among stakeholders to accelerate the transition towards sustainable port operations through workshops, training programs and collaborative initiatives. These outcomes highlight the comprehensive approach of the SEANERGY project in driving sustainable practices in ports while fostering collaboration, innovation and policy advocacy for a greener maritime industry.

The development and implementation of an energy transition and decarbonization Master Plan in ports contributes significantly to the decarbonization of the sector by reducing carbon emissions associated with port operations, encouraging the adoption of renewable energy sources, fostering innovation in clean energy technologies within the port industry and setting an example for other industries to follow suit in their sustainability efforts. In conclusion, the development of a comprehensive Master Plan for energy transition and decarbonization is imperative for ports to adapt to changing environmental norms, enhance operational efficiency, comply with regulations, and contribute positively to global sustainability goals.

7.3. Interports as Attractors of Economic Activity. The Experience of Consorzio ZAI

Alberto Milotti

Interports are proper enablers of a transportation system that today more than ever is characterized by a complex integration of multiple networks and modes. In this sense, the significance of interports is of strategic importance in the transportation infrastructure landscape especially in light of the role they play in strengthening the European Union's internal market.

In fact, as hubs strongly connected with ports, industry and consumption, they represent the ideal entity to develop new models of logistics outsourcing in close connection with rail services.

According to the definition given in Art. 1 of Law 240/1990, which planned and financed their implementation more than thirty years ago, interports are "an organic complex of facilities and services integrated and aimed at the exchange of goods between different modes of transport, in any case including a rail yard suitable for training and receiving complete trains and in connection with ports, airports and major roadways". Key factors for their development in Italy were:

- proximity to the basins of production and consumption (industrial areas and densely populated areas) given that the purpose of these infrastructures is to facilitate the distribution of goods over both medium/long and short distances;

- proximity and ease of connection with major road, highway and rail routes and sometimes interconnection with internal waterways or seaports.

The existing interports in the national territory are a reflection of the marked geographical differences present in the different areas of the country; in their geographic location they take into account the strong imbalances between Italian regions which characterized by different production structures and varied lifestyles and habits of consumption. They were created with the objectives of encouraging a modal rebalancing in favor of rail transport and increasing the efficiency of logistics services through the concentration of multiple activities in a single infrastructure node. Since their inception, they have made an important contribution to the development of a new logistics offering by industry players (shippers, MTOs, couriers, etc.). The competitive conditions for the real presence of an interport are:

- The achievement of a size and operational level that allows for economies of scale in the services offered;
- the provision of a wide range of transportation, distribution and logistics services;
- the coordination with other logistics facilities, both horizontally with similar facilities (other interports, ports of call and freight centers) and vertically with nodes at a lower (logistics platforms) or higher level (seaports);
- the capacity to attract logistics operators in order to rationalize traffic flows.

The functions and services performed within an interport are diverse and related to the facilities operating in it (typically a rail, logistics, customs and service area for people, goods and vehicles or cargo units). Specifically:

- the railway zone consists of a railway yard for train pickup and delivery, one or more intermodal terminals (necessary to enable the interchange between different

modes of large cargo units, such as containers, swap bodies, and semi-trailers), and junctions with warehouses, to enable the loading and unloading and storage of goods from wagons to warehouses;
- The logistics zone, on the other hand, consists of different types of warehouses for shippers (medium to large goods traffic), couriers (groupage traffic), and third-party logistics operators, whose main activity is warehouse management on behalf of companies that have decided to outsource product storage, processing, and distribution activities.

In the current economic juncture, interports must adopt an industrial connotation in the delivery and organization of services, striking the right balance between effectiveness and efficiency in storing products arriving from remote places and providing all the ancillary services useful in making the product more competitive in the final market.

Interports in Northern Italy have grown by connecting with local production systems, which have enabled their development. In particular, Interporto Quadrante Europa in Verona operates along the Brenner route in connection with Northern Europe and at the same time provides services to Veronese companies for their economic interchange with Germany, the Scaliger territory's first trading partner.

Due to ongoing geopolitical events, coupled with reshoring policies conducted by several Italian companies, trade within Europe is expected to grow in volume and importance. It is unimaginable that the growing volumes will be handled by road transport alone. A large part will have to be entrusted to rail transport. through new intermodal road-rail services. Precisely for these reasons, an interport such as the one in Verona, within which about 130 companies are located and where a total of about 2,500 people work (rising to 12,000 considering indirect and induced employees) is proposed as a promoter and engine of growth and development for new models of logistics outsourcing, new services of excellence, green logistics centers, vehicle recharging stations with alternative and more environmentally friendly fuels than diesel – such as bio-diesel, HVO (diesel produced from 100% renewable raw materials), LNG (liquefied natural gas), biomethane and electricity. Moreover, as a node strongly connected with ports, industry and consumption, it is the ideal entity to develop new models of logistics outsourcing in close connection with rail services. The goal of the Verona interport, also in light of recent settlements in the area, is to increase the share of intermodal transport coming from warehouses located within the infrastructure itself.

In addition, Verona intends to promote new solutions for the urban distribution of goods and new models for the operational management of warehouses, capable of giving flexible answers in the short term in terms of time and space with a focus on broadening its strategic vision by becoming a territorial development agency for the Verona area, combining resources in production, logistics, urban planning and services in order to make the territory of reference more competitive.

Against this backdrop, it is possible to glimpse the evolution of the offer and features of interports in general and that of Verona in particular for the next few years, in line with the following trends: the development of logistics outsourcing by companies, a recurring demand for high-quality logistics centers, a greater flexibility of use, in time and location of spaces – in any case able to offer a wide range of services to the entire logistics chain – to cope with flows related to the evolution of trade and production.

8. European Logistics: Multimodality as a Response to Geopolitics and Climate Change

Magda Kopczynska

Climate change and geopolitical developments are posing new challenges in Europe, such as the need to identify alternative routes when disruptions occur, as well as the long-term requirement of addressing the shift towards shorter value chains and nearshoring strategies while making transport sustainable and green. The war in Ukraine compelled us to seek solutions and adapt to traffic disruptions. Similar challenges arise during natural disasters like landslides or heavy floods, which can block sections of our network and lead to traffic disruptions with heavy losses for transport industry and economy in general. Now, more than ever, achieving optimal interoperability conditions both for infrastructure and digitalization is crucial for efficient intermodal transport, fully benefiting the competitiveness of the single European market.

Drawing Insights from the War in Ukraine and the Establishment of EU Solidarity Lanes: Reflections and Way Forward

In May 2022, the Commission established the "EU-Ukraine Solidarity Lanes" to help Ukraine overcome the blockade of the Black Sea and allow the country to continue exporting and importing goods via rail, road and inland waterways. Since then, the Solidarity Lanes have become critical corridors for Ukraine's agriculture exports, contributing to feeding the world. These corridors are also key to keeping the Ukrainian industrial capacity running with necessary imports during the vile war of aggression of Russia. Solidarity Lanes are not only facts but also figures: between May 2022 and March 2024, the Solidarity Lanes allowed Ukraine to export around 131 Mt (million tons) of goods, around 73 Mt of agricultural products and 58 Mt of non-agricultural goods. At the same time, thanks to the Solidarity Lanes, Ukraine could import around 50 Mt of goods. The total value of trade via the Solidarity Lanes is estimated at around €149 billion, with around €48 billion for Ukrainian exports and around €101 billion for Ukrainian imports.

Investments in Solidarity Lanes infrastructure represent above €1 billion joint pledge between the European Commission and international financial institutions. These investments are already having an impact at the EU-Ukraine borders and along the Danube corridor. The Connecting Europe Facility (CEF) has been instrumental in supporting complex transport infrastructure projects, fostering cross-border coordination with a first tranche of €250 million of grant funding, generating €500 million investments. Substantial funding has already been mobilized, but this is far from being enough. Our priority should be to ensure that the next Multiannual Financial Framework duly considers these needs.

The Solidarity Lanes have delivered due to the concerted efforts of all partners involved, ranging from transport companies to infrastructure managers and authorities. It is important to note the positive impact of the Road Transport Agreements between the EU and Ukraine and Moldova that helped boosting road transport between the EU and these two countries. With the development of the Baltic Sea-Black Sea – Aegean Sea (BBA) European Transport Corridor, we are entering into a new phase that requires updating the Solidarity

Lanes to additional short and long-term objectives, shifting from Solidarity to Connectivity.

Crisis resilience

Ukraine offers a very good example on how the transport system was resilient despite the enormous pressure on it deriving from Russia's war of aggression. Ukrainian authorities have been able to re-route high volumes of cargo to secondary inland waterway ports which have been, together with other Solidarity Lanes corridors, for several months the only way to connect Ukraine with the rest of the world. This has led to the development of additional capacity in the infrastructure – in particular in the port of Constanta – to satisfy Ukraine's grain export needs. In 2023, Ukraine relaunched transport operations from the Black Sea ports very swiftly still under war threat. After more than half a year of activity, the traffic volumes reached almost 5 Mt of grain every month, exceeding the pre-war levels.

This example shows that two elements are critical to improve the resilience of the transport network. First, transport corridors must be multimodal and should rely on alternative modalities when one or more modes are disrupted and cannot function properly. For instance, when the route to the Black Sea ports was interrupted, it has been possible to re-route the traffic to secondary ports, located in Ukraine but also in Moldova and in Romania. The second lesson learnt is that such an achievement would not have been possible without a strong coordination with the authorities, operators and transport stakeholders of the neighboring countries and with the steering role played by the European Commission.

Re-routing traffic, such as the one that was needed for Ukraine, can require significant financial resources if not adequately prepared. The European Commission was able to lower this cost by supporting small scale infrastructure improvements and by removing unnecessary administrative barriers to improve the transport offer and developing new routes that could better respond to the need to Ukrainian business for exports but also for imports.

In this context, the development of multimodal transport solutions is key to overcome potential blockades of a route. Making the best use of the existing infrastructure and having the capacity to shift from one mode to another made the Solidarity Lanes and other EU-funded projects aimed at developing multimodal capacity in the Danube area a success.

Rebuilding the connectivity

We are also looking forward, and changing our perspective, from emergency to connectivity and from partnership to accession to the EU. Our efforts should now focus on paving the ground for the future sustainable connectivity with Ukraine and Moldova in view of their future integration into the EU. These developments represent another key common challenge that we will have to cope with in the coming years.

The transport system will play a key role for the recovery of Ukraine: stronger transport connectivity and in particular trans-European transport connections will be key to build back the country. In the case of Ukraine, this political ambition needs to be supported by an equivalent commitment in terms of financing the infrastructure reconstruction and modernization. Our first key decision, in the framework of the revision of the TEN-T Regulation that will soon enter into force, was the extension of four European Transport Corridors towards Ukraine and Moldova:

- The Baltic Sea – Black Sea – Aegean Sea Corridor which is essential for Ukraine and also for Moldova;
- The Rhine – Danube Corridor which is key to connect Ukraine to the rest of Europe, using a sustainable transport mode;
- The Mediterranean Corridor;

and finally,

- The North Sea - Baltic Corridor.

These four extended European Transport Corridors will be the backbone of the future connectivity between Ukraine and Moldova and the EU and a key asset in view of their future accession. Developing rail interoperability[1] – by deploying EU standard track gauge in Ukraine and Moldova - is in this context one of our key priorities. The challenge is not only to build new EU gauge tracks but to ensure that the two rail systems – 1520 mm gauge and the 1435 mm – can operate smoothly during the transition from the old to the new one. But all these paths will also require a profound reform process to ensure that Ukraine and Moldova align their legislation with the EU legislation. This will require time and investments also in terms of human resources. Building a new transport system in Ukraine and Moldova will also require the training of people to get the expertise to work with the new deployed technologies (such as ERTMS for instance) but also people able to manage large and complex infrastructure projects which planning will be aligned with the EU legislation in terms of environment assessment, tendering or public consultation. This is a key challenge often considered as a secondary one but that deserves an immediate priority.

Beyond infrastructure and skilled workforce, it is important to build upon a clear strategy for transport in Ukraine. The country needs to build a resilient, decarbonized, multimodal and economically sustainable transport system. This is not an easy task. For instance, rail transport in Ukraine is not mirroring the last 50 years of developments in the EU. Ukrainian railways transport high volumes of freight bulk, while there is relatively little passenger traffic. Improving infrastructure will

[1] The rail track gauge in Ukraine and Moldova differs from the European standard nominal track gauge, with measurements of 1520 mm and 1435 mm, respectively. For more information, refer to the EC EIB Jaspers study "Strategy for the EU integration of the Ukrainian and Moldovan rail systems", which can be found at https://transport.ec.europa.eu/system/files/2023-07/Integration_of_the_UAMD_railway_system_into_the_EU_transport_system.pdf, published in July 2023.

necessitate strong reforms across all sectors, as well as in terms of intermodality by enhancing connectivity between rail and road networks.

We need new strategic objectives to make connectivity with Ukraine a booster for its recovery and reconstruction, as well as with Moldova.. Now we have to look at long term developments while keeping in mind unforeseeable changes regarding the access to the Black Sea. The transport system must be robust, reliable and interoperable with the EU TEN-T infrastructure. This is a crucial step for their future EU membership.

EU Legislative Initiatives: Shaping Resilient Logistics Chains to Adapt to Geopolitical Shifts and Climate Challenges

The EU transport infrastructure and logistics platforms will have to become resilient, both to the changing geopolitical environment and to the changing climate. Enhancing seamless multimodality and interoperability is fundamental for building a resilient network. The completion of a high quality TEN-T network with alternative routes in case of disruptions, will contribute to a better resilience of the transport system.

While the EU advocates for sustainable transport modes, road transport still dominates, accounting for over 54% of freight transport volumes in 2021.[2] Road transport is not only cheaper in many instances, but also very flexible to organise along the supply chain. Further, it provides the flexibility needed to collect and deliver goods from every place in the EU – neither trains nor barges are able to offer such door-to-door services. Rail and waterborne transport might be cheaper per ton-km, but the cost of transhipment and of organizing the supply chain, plus the additional time needed, mean that today

[2] European Commission, Directorate-General for Mobility and Transport, EU transport in figures – Statistical pocketbook 2023, available here: https://transport.ec.europa.eu/facts-funding/studies-data_en

combined or intermodal transport is only really competitive over a distance of more than 800 km.

Hence, to foster a sustainable multimodal transport system, enhancing intermodality and complementarity between modes is needed. We should be able to combine the flexibility of road transport with advantages of the other modes, while ensuring interoperability. Achieving this requires: (1) the creation of market conditions that make it attractive for freight operators to start combining transport modes and (2) the implementation of appropriate infrastructure, including logistic platforms. The European Commission succeeded in adopting several legislative measures to achieve this objective.

Improving market conditions

The Commission presented in July 2023 the Greening Freight package, which will make freight transport more efficient and sustainable by improving rail infrastructure management, by offering stronger incentives for low-emission lorries, and by providing transparent information on freight transport greenhouse gas emissions.

In November 2023, the Commission presented the related proposal to amend the Combined Transport Directive, to reduce our reliance on road-only freight transport by combining transport modes, hence lowering CO_2 emissions, reducing congestion, and offering a more efficient use of our transport network, and greater safety. Despite the growth of combined transport in the past three decades, its full potential remains largely untapped. The proposed Directive aims to address this by eliminating existing regulatory barriers and by encouraging increased support from Member States, thus fostering the best market environment for combined transport to flourish.

Another important element for improved market conditions is digitalization. A key legislation that was adopted in 2020 is Regulation (EU) 2020/1056 on electronic freight transport information (eFTI). Its objective is to make paperless transport a reality by 2030 – hence significantly reducing administrative burden, both for businesses and authorities. The Regulation promotes a multimodal approach, harmonizing requirements for exchanging freight transport information across road, rail, inland waterways, and aviation, through the same IT platform.

Ensuring that the right infrastructure is in place

The revised TEN-T Regulation[3] will significantly step-up efforts in building a sustainable, seamless and resilient transport network at the highest quality standards, by including incentives to use sustainable forms of transport and by improving the multimodality of our transport system.

The multimodality of the freight transport network in Europe is currently hampered by different factors: an insufficient number of efficient transfer hubs for freight allowing for a smooth transfer between modes, an insufficient performance of rail and inland waterways for long haul transport, the lack of certain technical standards as well as the slow implementation of digital tools. All these issues have been addressed in the revised TEN-T Regulation.

For instance, there is still a lack of sufficient multimodal terminal infrastructure in Europe, which is essential to foster combined transport. The revised TEN-T Regulation addresses this problem, in particular by incentivizing the development and adequate distribution of multimodal freight terminals with adequate transhipment capacity across Europe. To this aim, the TEN-T Regulation requires that each of the 431 urban nodes[4] provides for at least one multimodal freight terminal.

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[3] Footnote to be added with reference to the approved TEN-T revised Regulation, to be published in the Official Journal of the European Union.

[4] The 431 urban nodes can be seen on the maps of the TENtec: https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html. In accordance with Article 3 of the revised TEN-T Regulation (...), "urban node" means an urban area where elements of the transport infrastructure of the trans-European transport network for passengers and freight, such as ports, including passenger terminals, airports, railway stations, bus terminals and multimodal freight terminals, located in and around the urban area are connected with other elements of that infrastructure and with the infrastructure for regional and local traffic, including infrastructure for active modes.

Member States will also have to carry out a market and prospective analysis, involving transport and logistics operators and shippers, to determine where additional terminal capacity is required on their territory, on which basis they shall develop an action plan.

At the same time, the terminals on the TEN-T network shall become more digital and greener: by 2030 they need to be equipped with digital tools to ensure efficient terminal operations and with alternative fuels infrastructure dedicated to serve heavy-duty vehicles.

Finally, another important element of the revised TEN-T Regulation to promote combined transport, is the introduction or reinforcement of a number of infrastructure standards: for instance, the new requirement for the main corridor rail freight lines to enable the circulation of freight trains carrying standard semi-trailers up to 4 meters high, loaded at a height of at least 27 centimeters above the top of the rail track. Road-rail combined transport using semi-trailers has a very dynamic segment of rail freight in the last ten years and accounts for around 20% of traffic of the major operators of intermodal transport in the EU. At the same time, the circulation of semi-trailers is currently not possible on a significant portion of the TEN-T, which is why the revised Regulation addresses this issue.

By setting ambitious infrastructure standards for all transport modes, combined with reinforced governance instruments to ensure the timely realization of the TEN-T network, a real step forward can be made for the promotion of combined transport across Europe.

Concluding Remarks

In conclusion, when fully implemented, these initiatives will fortify the European transport system against external disruptions, foster its resilience, align the network with the ambitious objectives of the European Green Deal, and accommodate to the evolving dynamics of an EU aspiring for greater autonomy while maintaining openness and bolstering competitiveness. It is imperative for the EU and the Member States, to ensure that the necessary resources are allocated to facilitate a successful implementation, making this a critical focus in the forthcoming preparation of the next EU Multiannual Financial Framework.

As regards Ukraine and Moldova, it is imperative to reach strategic objectives aimed at improving their connectivity with the EU. It is essential to prioritize the development of a robust, reliable, interoperable, and intermodal TEN-T infrastructure with the neighboring countries. This is a crucial step towards the future EU membership of these countries.

9. China's Port Investments Abroad: The Players and the Implications for a Global Influence

Zongyuan Zoe Liu

China has become the world's largest trading country and second-largest economy. Maritime trade is important for China's international trade, as 95% is carried through sea lanes. Sea lane transportation handles almost all freight traveling between China and the Association of Southeast Asian Nations (ASEAN), and nearly 80% of Chinese export to Europe.[1] As of 2023, China and ASEAN have been each other's largest trading partners for four consecutive years.[2]

The launch of the Belt and Road Initiative in 2013 by Chinese President Xi Jinping and the introduction of the Twenty-First Century Maritime Silk Road (MSR), which connects China to Europe and the Arctic Ocean via the South China Sea and the Indian Ocean, have supercharged China's overseas port investment and construction activities. MSR is important for

[1] "李克强考察中远比雷埃夫斯集装箱码头, ("Le Keqian inspects COSCO Piraeus Container Terminal", *Xihua News*, 21 June 2014); "李克强访欧搭中欧陆海快线　缩减海运时间7–11天" ("Li Keqiang visits Europe and takes the China-Europe Land-Sea Express Line, which is to reduce shipping time by 7-11 days", State Council news, 19 December 2014).

[2] "Looking into the Future Seeking Common Development To Advance the Building of a Closer ASEAN-China Community with a Shared Future", Ambassador Hou Yanqi's keynote remarks at the inauguration for the ASEAN-China Research Center in University of Indonesia, 4 March 2024.

trade, considering that 90 percent of globally traded goods are transported via ocean shipping, with an estimated 53 percent of global sea trade passing through ports located in BRI countries.[3]

President Xi has personally emphasized the importance of ports for economic development. When visiting Tieshan Port in Guangxi Province in April 2017, Xi highlighted the importance of ports in economic development: "We often say that to get rich we must first build roads; but in coastal areas, to get rich we must also first build ports". Since the 18th National Congress of the Communist Party of China, General Secretary Xi has repeatedly stressed the importance of building China as a maritime power, stating that "an economic power must be a maritime power and a shipping power".[4] The report of the 20th National Congress of the Communist Party of China made major arrangements to "accelerate developing China as a maritime power".[5]

As of September 2023, China has signed seventy bilateral and regional shipping agreements with sixty-six countries and regions.[6] Today, China's shipping routes and service networks cover major countries and regions worldwide. China's state-owned entities have built, expanded, or invested in over one hundred port projects worldwide, with ninety port projects still active across six continents. The largest port project

[3] "Belt and Road Economics: Opportunities and Risks of Transport Corridors", The World Bank, 18 June 2019.

[4] President Xi Jinping has made such statement on many occasions since 2013. For example, "Comrade Xi Jinping's speech at the eighth collective study session of the Political Bureau of the CPC Central Committee" (习近平同志在中共中央政治局第八次集体学习时的讲话), 30 July 2013.

[5] "Promote Chinese-style modernization with new actions in building a maritime power", (以建设海洋强国新作为推进中国式现代化), 学习时报, 22 September 2023.

[6] "市政府新闻发布会介绍2023北外滩国际航运论坛总体安排和航运业发展情况" (Shanghai municipal government press conference introduced the overall arrangements of the 2023 North Bund International Shipping Forum and the development of the shipping industry), Shanghai Municipal Government press release, 12 September 2023.

investments are in South and Southeast Asia, the Atlantic Coast of Africa, Israel, and the Southeast of the Mediterranean. Chinese companies have a majority ownership share in thirteen port projects worldwide.[7] Although China is not yet a global naval power and currently has limited overseas naval bases, it has become a leading commercial power that wields significant geoeconomic influence over international sea lanes and commercial ports underpinning the global flow of goods.

Major Actors in China's Overseas Port Investments and Construction

While the BRI is China's flagship global infrastructure investment initiative launched by Chinese President Xi Jinping, the Chinese government started to seek for overseas port investment and cooperation before the launch of BRI in 2013. Since the launch of BRI, China's overseas port investments have increased and accelerated in terms of deals, geographic distribution, and participants. COSCO Shipping Ports (formerly COSCO Pacific) and China Merchant Port (CMPort), two central-government-owned enterprises (so-called *yangqi*, 央企) under the purview of the State-owned Assets Supervision and Administration Commission (SASAC), are two major Chinese port terminal operators that have invested in overseas ports since before the launch of BRI.

With Chinese local governments participating in BRI, local port groups have also increased their overseas port investment. Before BRI, Shanghai International Port Group (SIPG) was the only local port group that had invested in overseas ports, but more local ports across Chinese coastal provinces joined the trend after the launch of BRI. In 2010, SIPG acquired a 25 percent stake in APM Terminals' Zeebrugge Port in Belgium

[7] Z.Z. Liu, "Tracking China's Control of Overseas Ports", Council on Foreign Relations, 6 November 2023.

for $33.3 million.[8] Since the launch of BRI, more local port groups have embarked on overseas port investments. The number of overseas port investments by Chinese companies has visibly increased.

To date, central-government-owned port operators, such as COSCO Shipping Port and CMPort, and central-government-owned constructors and builders, such as China Communications Construction Group and its subsidiaries, remain the primary participants in overseas port projects investment and construction, sometimes with financial participation from Chinese sovereign funds such as China Investment Corporation and policy banks such as Export-Import Bank of China and China Development Bank. COSCO Shipping Port and CMPort accelerated their overseas investment amid the 2007-08 global financial crisis, as the crisis created economic opportunities and reduced political resistance to China's overseas port investment. The negative shock of the financial crisis to the global economy and international trade directly led to a downturn in the global shipping market, which caused difficulties for port operations and depreciating port assets' valuations. Many port operators had to sell their assets to alleviate their liquidity shortage, creating acquisition opportunities on the market. Additionally, as foreign governments struggled to raise funds to alleviate the impact of the financial crisis, they relaxed review and supervision over investments made by Chinese companies, reducing the political obstacles and hidden barriers to China's overseas port investment.

COSCO Shipping Ports

COSCO Shipping was the first Chinese port logistics service provider to invest in overseas ports. It was formed in January

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[8] "Shanghai International Port to buy stake in Belgium port", *Port News*, 1 June 2010.

2016 by a merger of China Ocean Shipping Company (COSCO) and China Shipping Group. In 2003, COSCO Pacific started investing in overseas ports in Southeast Asia by forming a joint venture, COSCO-PSA Terminal (CPT), with Singapore's PSA International. COSCO Pacific owns 49% equity shares in the joint venture that manages two berths at Pasir Panjang Terminal in two phases.[9]

In 2004, COSCO Pacific entered the port business in Europe and the Mediterranean by acquiring a 25% interest in Antwerp Gateway through its subsidiary COSCO Ports (Belgium).[10] The same year, it began container services to Greece and later expressed interest in investing in Greek ports in 2007.[11] In 2007, COSCO completed the purchase of a 20 percent equity share in the Suez Canal Container Terminal at Port Said located at the northern end of the Suez Canal from Egyptian International Container Terminal S.A., a subsidiary of A.P. Moller-Maersk. The deal was first announced in 2005.[12]

As the global financial crisis hit European economies hard after 2007, COSCO Pacific accelerated its investment in European ports as European governments and their ports faced financial difficulties. For example, it invested in Piraeus Port in 2008 when the Greek government was grappling with a massive debt crisis and potential default. COSCO agreed to pay €831 million to lease two piers at Piraeus Port for up to 35 years. It also agreed to spend €235.5 million to upgrade Pier 2 and build Pier 3.[13] When visiting the COSCO-operated container terminal in 2014, Chinese Premier Li Keqiang referred to Piraeus Port as "the Pearl of China-Greece Cooperation".

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[9] COSCO Pacific Limited 2003 Annual Report.

[10] COSCO Pacific Limited disclosable transaction note via the Sock Exchange of Hong Kong.

[11] "China's COSCO eyes Greek port investments", *Ekathimerini.com*, 5 June 2007.

[12] "COSCO Pacific buys 20% stake in Suez Canal Container Terminal", *American Shipper*, 4 November 2007.

[13] "Cosco Pacific to lease 2 piers at Greek port", *South China Morning Post*, 30 October 2008.

According to Premier Li, the land-sea route through Piraeus Port is the shortest sea lane from China to Europe, which can shorten transportation time by 7 to 11 days compared to the traditional shipping route.[14]

Since the launch of BRI, COSCO Shipping has accelerated its global network of ports and terminals across Asia, Europe, America, Africa, the Mediterranean, and the Middle East. (Table 9.1). According to COSCO chairman Wan Min, as of 2023, COSCO Shipping has established ten regional companies overseas, invested and operated 59 terminals worldwide, and operated 348 container routes covering 1,500 ports in 160 countries.[15] COSCO 2023 Annual Report disclosed that as of 31 December 2023, COSCO Shipping Ports operates and manages 371 berths in 38 ports around the world, of which 224 are container berths.[16]

China Merchants Port

China Merchants Port Holdings Company (CMPort), renamed from China Merchants Holdings (International) Company (CMHI) in 2016, is a Hong Kong-based global terminal operator owned by China Merchants Group.[17] CMHI started to invest in overseas ports in 2008 amid the global financial crisis.

[14] "李克强考察中远比雷埃夫斯集装箱码头, ("Le Keqian inspects COSCO Piraeus Container Terminal"…, cit.); "李克强访欧搭中欧陆海快线 缩减海运时间7-11天" (Li Keqiang visits Europe and takes the China-Europe Land-Sea Express Line, which is to reduce shipping time by 7-11 days…, cit.).

[15] "扬帆海洋强国新航程" (Set sail for a new voyage of maritime power), 红旗文稿 (*Red Flag Manuscript*), March 2023.

[16] "中远海运控股股份有限公司 2023 年年度报告" (COSCO Shipping Holdings Co., Ltd. 2023 Annual Report).

[17] Proposed Chage of Name by China Merchants Holdings (International) Company Limited, 31 March 2016.

Tab. 9.1 - COSCO Shipping Ports Overseas Port Aquisitions and Ownership

Year	Name of Port and Terminal	Country	Ownership
2001	Port of Long Beach	U.S.	51%
2003	Pasir Panjang Terminal	Sinapore	49%
2004	Port of Antwerp	Belgium	25%
2007	Port Said East Port Container Terminal 1 Project	Egypt	20%
2008	SSA Terminal (divested in 2018)	U.S.	33%
2009	Terminal expansion in Piraeus Port container terminals 2 and 3	Greece	35-year franchise
2015	Kumport wharf	Turkey	26%
2015	Korea Express Busan Container Terminal (KBCT) Terminal	South Korea	20%
2016	Piraeus Port	Greece	67%
2016	Rotterdam EUROMAX Container Terminal	Netherlands	35%
2016	Vado Reefer Terminal via Vado Holding B.V.	Italy	40%
2016	Kumport Terminal	Turkey	26%
2016	Khalifa Port, Abu Dhabi	UAE	90%
2017	Singapore Pasir Panjang New Berth Project	Singapore	49%
2017	Noatum Container Terminal Valencia, S.A.U	Spain	51%
2017	Noatum Container Terminal Bilbao, S.L.	Spain	51%
2017	Zeebrugge Container Terminal	Belgium	100%
2019	Chancay Terminal	Peru	60%
2022	Hamburg Port Container Terminal Tollerot	Germany	24.99%
2023	Sokhna New Container Terminal	Egypt	25%

Source: Author compiled data from publicly available data. Also see, Z.Z. Liu, Tracking China's Control of Overseas Ports, an interactive map tracks China's overseas port investments.

In 2008, CMPort signed cooperation agreements with Vietnam National Shipping Lines (Vinalines) and Petrovietnam-PVN to establish a joint venture, named Vung Tau International Container Port Company, to construct and operate the Ben Dinh Sao Mai Deep Seaport in Vietnam.[18] The joint

[18] China Merchants Port Holdings Company official website, company history; China Merchants Holdings public release on the Stock Exchange of Hong Kong; and China Merchants Holdings (International) company magazine, June 2008, p. 1, p. 7, and p. 15, available at

venture was launched in 2010. Through its subsidiary CM Vietnam, CMHI owns 49 percent, whereas Vinalines and Petrovietnam-PVN each own 26 percent and 25 percent.[19] In 2010, CMHI and China-Africa Development Fund set up a 60/40 joint venture to acquire a 47.5% stake of the Tin Can Island Container Terminal in Laos, Nigeria, from Israel's Zim Integrated Shipping for $154 million.[20]

CMHI entered the port business in Sri Lanka shortly after the country ended a three-decade civil war in May 2009. In 2011, CMHI signed a BOT agreement to construct and manage the Colombo South Container Terminal for 35 years. Per the agreement, CMHI, Aitken Spence Plc, and Sri Lanka Port Authority jointly established Colombo International Container Terminals (CICT), each owning 55%, 30%, and 15% of stakes in the joint venture, respectively.[21] In 2012, CMHI's equity interest in CICT increased to 85% after its acquisition of an additional 30% stake in the joint venture.[22] It then acquired a 50% stake in Togo's Port of Lomé Container Terminal from Terminal Investment Limited S.A. Group, one of the world's top ten container terminal operators.[23] In February 2013, CMHI completed the acquisition of a 23.5 percent state in Port de Djibouti from the Djibouti Port and Free Trade Zone Authority.[24] CMHI was able to further expand its global presence by partnering with CMA CGM, then the world's third-largest container

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[19] China Merchants Port Holdings Company official website, company history for the year 2010, accessed at

[20] China Merchants Port Holdings Company official website, company history, and "China Merchants buys into Lagos container terminal", *Seatrade Maritime News*, 9 November 2010.

[21] "China Merchants Group signs BOT agreement for Colombo Port South Container Terminal project" (招商局集团签署科伦坡港南集装箱码头项目BOT协议), State-owned Assets Supervision and Administration Commission news release, 15 August 2011. Also, China Merchants Port Holdings Company official website, company history.

[22] China Merchants Port Holdings Company official website, company history.

[23] Ibid.

[24] Ibid.

shipping company with headquarters in Marseilles, France. In June 2013, CMHI completed its €400 million acquisition of a 49% equity stake in Terminal Link, an international container terminal operator, developer, and investor established in 2001 by CMA CGM. At that time, Terminal Link owned 15 container terminals in 8 countries across four major continents.[25] Terminal Link now has interests in 50 terminals worldwide and remains a 49/51 joint venture between CMPort and CMA CGM.[26] According to the CMPort 2023 Annual Report, it has a presence in 46 ports in 26 countries and regions on six continents.[27]

Tab. 9.2 - CMPort Overseas Port Acquisition and Ownership

<table>
<tr><th>Year</th><th>Name of Port and Terminal</th><th>Country</th><th colspan="2">Ownership</th></tr>
<tr><td>2008</td><td>VICP</td><td>Vietnam</td><td colspan="2">49%</td></tr>
<tr><td>2010</td><td>Port of Hambantota</td><td>Sri Lanka</td><td colspan="2">64.98%</td></tr>
<tr><td>2010</td><td>Vung Tau Container Terminal</td><td>Vietnam</td><td colspan="2">49%</td></tr>
<tr><td>2010</td><td>Lagos Tin Can Port Container Terminal (TICT)</td><td>Nigeria</td><td colspan="2">28.50%</td></tr>
<tr><td>2011</td><td>Colombo International Container Terminal (CITC)</td><td>Sri Lanka</td><td>55%</td><td rowspan="2">85%</td></tr>
<tr><td>2012</td><td>Colombo International Container Terminal (CITC)</td><td>Sri Lanka</td><td>30%</td></tr>
<tr><td>2012</td><td>Lomé Container Terminal</td><td>Togo</td><td colspan="2">50%</td></tr>
<tr><td>2013</td><td>Djibouti Container Terminal</td><td>Djibouti</td><td colspan="2">23.50%</td></tr>
<tr><td>2013</td><td>Terminal Link</td><td>France</td><td colspan="2">49%</td></tr>
<tr><td>2013</td><td>Bagamoyo Port</td><td>Tanzania</td><td colspan="2">NA</td></tr>
<tr><td>2014</td><td>Zarubino Port</td><td>Russia</td><td colspan="2">NA</td></tr>
<tr><td>2014</td><td>Newcastle Port</td><td>Australia</td><td colspan="2">50%</td></tr>
<tr><td>2015</td><td>Kumport Terminal</td><td>Turkey</td><td colspan="2">26%</td></tr>
<tr><td>2015</td><td>Kyaukpyu Port</td><td>Myanmar</td><td colspan="2">NA</td></tr>
<tr><td>2017</td><td>Paranagua Port Terminal (TCP)</td><td>Brazil</td><td colspan="2">90%</td></tr>
<tr><td>2017</td><td>Hambantota Port</td><td>Sri Lanka</td><td colspan="2">70%</td></tr>
</table>

Source: Author compiled data from publicly available data. Also see, Z.Z. Liu, Tracking China's Control of Overseas Ports,

[25] "CMHI and CMA CGM complete the Terminal Link Transaction", CMA CGM press release, 11 June 2013.

[26] "Our activities" on CMA CGM Group website.

[27] CMPort Annual Report 2023.

China Communications Construction Group

The primary contractors and builders for China's overseas port projects have been China Harbor Engineering Company (CHEC) and China Road and Bridge Corporation (CRBC). In December 2005, CHEC and CRBC merged and restructured to form a bigger central-government-owned conglomerate, China Communications Construction Group (CCCC), under the purview of SASAC. CHEC and CRBC have since been two major subsidiaries of CCCC. Besides being Asia's largest international engineering contracting company and China's largest highway investor, CCCC today tops the world along several dimensions according to the company's own introduction: it is the world's largest port design and construction company, the world's largest highway and bridge design and construction company, the world's largest dredging company, the world's largest container crane manufacturing company, and the world's largest offshore oil drilling platform design company.[28]

As a subsidiary of CCCC, CHEC embarked on overseas port construction before the launch of BRI alongside major Chinese policy banks. For example, in March 2007, CHEC and Sri Lanka Port Authority signed the first phase construction contract for Sri Lanka's Hambantota Port with a value of $361 million and a contract period of 39 months.[29] Besides being an important port in southern Sri Lanka, Hambantota Port is the hometown of then-President Rajapaksa. To finance the project, the Export-Import Bank of China and the Sri Lanka government signed a loan agreement in October 2007, with the Chinese policy bank providing the Sri Lanka government export buyer's credit, a medium- and long-term financing

[28] CCCC's company introduction, available ta https://www.cccltd.cn/aboutus/gsgk/

[29] "中交中国港湾签署斯里兰卡汉班托塔港发展项目" ("CCCC China Harbor Engineering Co., Ltd. signed the Hambantota Port Development Project in Sri Lanka", State-owned Asset Supervision and Administration Commission of the State Council, press release, 23 March 2007).

facility provided by the Chinese policy bank and supported by the Sri Lanka government.[30]

Today, Chinese builders and contractors have expanded their activities beyond port terminals into designing, constructing, and developing the logistic areas around major ports. For example, in November 2022, CCCC and CRBC signed an agreement with a memorandum of understanding with Alexandria Port Authority regarding the preparation of the technical plan and the business model for the establishment, management, operation, and development of the logistics zone in Alexandria Port in Egypt.[31] By actively participating in developing port logistics, CCCC and its subsidiaries can directly support trade and apply China's standards for port logistic services in global ports.

Overseas Port Investments in China's Grand Strategy

The overseas port investment experience of *yangqi*, such as COSCO Shipping, CMPort, and CCCC, suggested that the start of China's overseas port investment was not with the launch of BRI, despite that the launch of BRI in the aftermath of the global financial crisis has accelerated China's overseas port investments. From the perspective of China's influence over international trade and development, *yangqi*'s dominant presence in China's overseas port investments and constructions was not always part of a accel Chinese grand strategy in which the CPC and Chinese government have figured out how to dominate global sealanes for security reasons.

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[30] "中国提供贷款建设的斯里兰卡汉班托特港正式开工" ("China provides loan to build Sri Lanka's Hambantota port officially opens") Chinese government news, 1 November 2007.

[31] "Transport Minister witnesses signing of MoU to establish, manage logistics area at Alex. Port", State Information Service of Egypt, 19 November 2022. Also, "Egypt signs MoU of operation for logistics area in Alexandria", *Amwal Al Ghad*, 20 November 2022.

In China's foreign policy narrative and practice, its promotion of overseas port investment did not begin with a grandiose global vision either. Instead, China's first attempt to promote port and logistics cooperation with foreign stakeholders started with a modest regional cooperation initiative co-hosted between a branch of the central government and a local government, and it did not have an explicit investment agenda. In October 2007, about a month after the collapse of the Lehman Brothers, China's Ministry of Transportation and the government of Guang Xi Province co-hosted the inaugural China-ASEAN Port Development and Cooperation Forum in Nanning, the capital city of Guang Xi. The forum was not an independent convention but was launched as a main theme of the 4th China-ASEAN Expo, which aimed to promote regional port and logistics cooperation.[32] Mr. Fu Yuning, then President of China Merchants Group, addressed the forum and discussed concrete measures taken by China Merchants Group to pursue port investments in ASEAN to serve the need of regional economic development.[33] In 2008, CMPort embarked on its first overseas port investment in Vietnam, as discussed in the previous section.

As various state-owned enterprises and financial entities at the central and local levels expand their overseas port investments, overseas port investment as an issue area has emerged in some government policy position papers and five-year plans. For example, in March 2015, with the authorization of the State Council. the National Development and Reform Commission, Ministry of Foreign Affairs, and Ministry of Commerce jointly issued a "Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road".[34] In

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[32] "中国–东盟港口发展与合作论坛开幕式" (Opening Ceremony of China-ASEAN Port Development and Cooperation Forum, Ministry of Transportation, 28 October 2007). Full transcript of speeches available at https://xxgk.mot.gov.cn/2020/jigou/zcyjs/202006/t20200623_3307445.html

[33] Ibid.

[34] "Vision and Actions on Jointly Building Silk Road Economic Belt and

this document, Chinese policymakers envisioned that "at sea, the Initiative will focus on jointly building smooth, secure, and efficient transport routes connecting major sea ports along the Belt and Road". Recognizing the need to support physical infrastructure with adequate software to improve logistics efficiency, they also proposed to "improve the customs clearance facilities of border ports, establish a 'single-window' in border ports, reduce customs clearance costs, and improve customs clearance capability".[35] Yet this policy position paper did not explicitly emphasize encouraging Chinese companies to invest in overseas ports

China's 13th Five-Year Plan for 2016-20 put port development on China's global development agenda. It proposed to "actively advance the construction of strategic maritime hubs along the 21st Century Maritime Silk Road, participate in the building and operation of major ports along the road, and promote the joint development of industrial clusters around these ports to ensure that maritime trade routes are clear and free-flowing".[36] To this end, it also specified geographic orientation and prioritized issue areas, including to "increase infrastructure connectivity with neighboring countries, build infrastructure networks that connect sub-regions within Asia as well as Asia, Europe, and Africa," to "build an international logistics park for the Shanghai Cooperation Organization and a China-Kazakhstan logistics cooperation center," and to develop "Fujian as the core region for the 21st Century Maritime Silk Road".[37]

Consistent with the 13th Five-Year Plan, China's 14th Five-Year Plan for 2021-25 explicitly called for promoting "integrated connectivity that comprises land, sea, air, and cyber links, build

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21st-Century Maritime Silk Road", issued by Issued by the National Development and Reform Commission, Ministry of Foreign Affairs, and Ministry of Commerce of the People's Republic of China with State Council authorization, 28 March 2015.

[35] China's 13th Five-Year Plan, p. 148.

[36] Ibid.

[37] Ibid.

a connectivity framework featuring 'six corridors, six routes, and multiple countries and ports,'" with the goal to "develop a connectivity network … and … create a new international land-sea trade corridor". [38] It vowed to "expand the influence of the 'Maritime Silk Road' as a brand" and advance the building of Fujian into a core area of BRI.

Global Implications of China's Control and Management of Overseas Ports

Chinese overseas port investments are not risk-free. Like any overseas investments, acquisition and ownership of foreign infrastructures are subject to a wide range of risks beyond the control of the Communist Party of China and the Chinese government. Some of China's pre-BRI investments in overseas ports later became controversial, with the cases of Hambantota Port investment and the Djibouti Port investment being two high-profile examples. The fact that COSCO Shipping and CMPort started to invest in these two ports before BRI did not prevent them from falling into controversies, often associated with the Chinese government's use of BRI for global influence. Hambantota Port investment has often been criticized as in association with the narrative of China's debt trap diplomacy in the context of BRI. In contrast, Djibouti Port investment has been cited as an example of China intending to expand overseas naval bases amid growing competition with the United States.[39]

Growing geopolitical tensions between hosting countries and China and national security concerns about Chinese entities' ownership of critical infrastructures, such as ports, have led to

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[38] China's 14th Five-Year Plan, Chapter 41.

[39] For example, J.P. Cabestan, "China's Military Base in Djibouti: A Microcosm of China's Growing Competition with the United States and New Bipolarity", *Journal of Contemporary China*, vol. 29, no. 125, 2020, pp. 731-47; I. Saxena, R. Uri Dabaly, and A.Singh, "China's Military and Economic Prowess in Djibouti: A Security Challenge for the Indo-Pacific", *Journal of Indo-Pacific Affairs*, 18 November 18, 2021.

forced divestment. For example, the Chinese company Orient Overseas had owned the Long Beach Container Terminal in California for over 30 years. However, after COSCO bought Orient Overseas in 2017, it was forced to sell off its entire stake in the container terminal to Olivia Holdings, majority-owned by a fund run by Macquarie Infrastructure and Real Assets, which in turn is part of Australia's Macquarie Group, as American security agencies found that the indirect control of a US port by a Chinese SoE was a national security risk.[40]

The basis of critiques for controversial port investments by Chinese entities varies by region. In South and Southeast Asia, debt trap, environmental, legal, quality of work issues, and potential military use risks are common concerns. In Europe, Australia, and the United States, the problem was primarily national security risks. In East Africa, concerns were associated the debt trap narrative and legal issues. In the Middle East and West Africa, critiques and concerns have been about potential military use risks. In South America, it was legal issues and quality of work concerns. In some cases, such concerns have led to project delays and even cancellations, suggesting the limits of China's overseas influence and the agency of hosting governments.[41]

As the US government continues pursuing industrial policies to incentivize companies to bring manufacturing back home and reduce supply chain dependence on Chinese suppliers, expanding new markets overseas has become an imperative issue for the Chinese government and companies. In this context, securing sea lane transportation and expanding overseas port logistics services are even more critical for China's international trade, especially with countries in the Middle East, Latin

[40] "COSCO's OOIL sells Long Beach terminal to Macquarie for $1.78 billion", *Reuters*, 29 April 2019; "US security concerns force Cosco-owned Orient Overseas to sell Long Beach port in California", *South China Morning Post*, 30 April 2019.

[41] Z.Z. Liu, "Tracking China's Control of Overseas Ports", an interactive map tracks China's overseas port investments.

America, and Africa, where land transportation is beyond reach and flight logistics are not always economical. After all, the Chinese economy and Chinese manufacturers depend on international trade.

While the Chinese government is aware of the potential security risk of US military dominance in global sea lanes in times of extreme geopolitical events, it is also aware that China's international trade benefits from the free and open sea lanes safeguarded by the US military. Heightened geopolitical tensions incentivize Chinese policymakers to strengthen the Chinese military and even attempt to strategize for overseas military base development. However, the likelihood of economic war between the United States and China is far greater than a militarized conflict. Thus, the need to reduce China's vulnerability in an economic war with the United States is much greater and more urgent. Even if military conflict is deemed inevitable, Chinese policymakers are likely to strengthen China's resilience against sanctions before they resort to war.

The availability of high-quality infrastructure is necessary but insufficient for efficient supply chain performance in international trade. High-quality logistics service is required to optimize delivery time, improve customer satisfaction, maintain supply chain resilience, and expand market shares. Furturemore, overseas port facilities can be augmented with free trade zones and e-commerce warehouses, the availability of which can facilitate the smooth flow of goods across borders. From this perspective, it would be unwise for the CPC and the Chinese government to prioritize expanding overseas military bases rather than securing commercial sea lanes and logistics. Additionally, western governments have increasingly become concerned about China's potential development of overseas naval bases. Although the growing scrutiny from the West could mean that building naval bases is not an effective way for the CPC and the Chinese government to project power globally, the CPC and the government can still influence global trade and logistics. China's heavy investment in the world's most-connected ports highlights its strong influence over the supply chains of global trade. The real leverage of the CPC and the Chinese government over the West is not necessarily in building newer and bigger naval bases; rather, China's leverage is in its varied degrees of investment and ownership in the world's busiest and most-connected ports, which underpin the global flow of goods.

10. America Deglobalizing: New Industrial and Infrastructure Strategies, Same Development Policies

Michael Bennon

The United States is deglobalizing and rebuilding its long-outsourced manufacturing sector. At least, that is the plan. American industry, and industrial policy, are currently undergoing a period of unprecedented change in an attempt to reverse decades of increasingly globalized (and geopolitically vulnerable) supply chains and outsourced manufacturing.

This coincides with the implementation of a series of federal infrastructure investment and industrial policy programs under the Biden Administration. All combined, these programs amount to what is easily the largest federal investment in a generation in transportation, energy and even manufacturing. Yet the degree to which America re-shores, or friend-shores, key manufacturing sectors and supply chains will necessarily be shaped by the capacity of the nation's infrastructure networks, and its ability to build.

This chapter includes a review of these transitions, policies and investment programs and the remaining challenges that the United States faces in deglobalizing and re-shoring manufacturing. My broad conclusion is that America's grand efforts at infrastructure investment and industrial policy will likely result in more friend-shoring, rather than re-shoring, unless additional policy reforms are implemented.

America's grand deglobalization project is actually comprised of two related but not completely overlapping transformations. The first transformation is towards more resilient manufacturing supply chains, which is primarily occurring by diversifying those supply chains away from China. The second, related transformation is a policy effort to re-shore manufacturing within the United States.

Both of these transformations are key objectives of the US federal government, and are largely bipartisan. Partisan differences, where they exist, are largely over the policy tools to use in accomplishing them. The Biden Administration, if reelected, will likely continue on its current course of industrial policy interventions and federal investment programs. A future Trump Administration may differ in its application of industrial policy and favor broader tariffs instead.[1] It may also curtail current subsidies focused on renewable energy infrastructure in particular.[2] However, the broader policy objectives of diversifying, if not "decoupling",[3] manufacturing away from China and re-shoring manufacturing domestically are almost completely bipartisan today.

The re-shoring and friend-shoring trends differ, however, in terms of their alignment between major American corporations and US public policy. The private sector in the United States today is almost completely aligned with (in fact, probably ahead of) the US government in diversifying supply chains out of China. The pace of the shift is startling – foreign direct investment (FDI) in China in 2023 plummeted to just 10% of its 2021 peak.[4] Heightened geopolitical tensions over Taiwan, trade disputes over Chinese manufacturing subsidies,

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[1] R. Hass, "How Will Biden and Trump Tackle Trade with China?", Commentary, Brookings Institution, 4 April 2024.

[2] "What a Second Trump Presidency Could Mean for US Energy Policy", *Reuters*, 16 February 2024.

[3] J. Sullivan, "The Sources of American Power", *Foreign Affairs*, 24 October 2023.

[4] I. Kawate and S. Tabeta, "Foreign Direct Investment in China Falls to 30-Year Low", *Nikkei Asia*, 19 February 2024.

the uncertainty around US tariffs, and lessons learned from Chinese lockdowns during the pandemic have all led major corporations to diversify supply chains away from China.

Whether all of that manufacturing capacity "re-shores" or "friend-shores" will largely be driven by American infrastructure and industrial policies. The Biden Administration has passed significant funding legislation in both of those areas, but it crucially has yet to reform American development policies to allow major infrastructure and federally supported manufacturing projects to be developed efficiently. The disconnect between America's infrastructure and industrial policies on the one hand and its development policies on the other will almost certainly constrain the ability of manufacturers to relocate supply chains domestically. Despite the administration's best efforts in supply chain management, industrial policy and infrastructure funding, the future is most likely in friend-shoring.

In the remainder of this chapter, I first review how American infrastructure needs to evolve to accommodate more resilient supply chains, domestic manufacturing growth, and the energy transition. Next, I review the Biden Administration's current infrastructure and industrial policies in key sectors. Finally, I review the key policy impediments that the US faces in re-shoring manufacturing and building the infrastructure necessary to support it.

Deglobalization and American Infrastructure

Deglobalization and the re-shoring of supply chains amid increasing geopolitical risks is one of the major trends impacting global infrastructure investment today.[5] That trend is truly global, however. Within the United States, infrastructure supporting supply chain reconfigurations and new industrial policy will primarily impact some transportation subsectors, the energy sector, and critical minerals.

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[5] "Why BlackRock Is Betting Billions on Infrastructure", *The Economist*, n.d.

Transport Infrastructure. Deglobalization will significantly shift demand between various subsectors within transportation, and the most immediate shift will likely occur in American port infrastructure. As more private firms diversify their supply chains out of China, and federal policy increasingly incentivizes companies to do the same, US imports will likely shift from a heavy reliance on a few major West Coast ports, such as the Port of Los Angeles and the Port of Long Beach, to major ports on the east coast. Early signs of US disengagement from China are already emerging in the US airport sector. For airports, traffic levels in many east coast airports has returned to pre-pandemic levels, while west coast airports more reliant on significant traffic from Asia have struggled to recover.[6] While shipping traffic between west coast and east coast ports has oscillated back and forth in recent years, containerized imports at east coast ports have increased markedly in aggregate since the pandemic, and the shift in imports from China to other countries is widely expected to continue the trend west to east in American port traffic.[7]

Other transportation sectors within the United States will remain important for supply chain resilience but will be unlikely to undergo a major transformation as a result of deglobalization. American freight rail and trucking infrastructure, while certainly aging and not expanding, are also flexible enough to accommodate shifts in domestic supply chains or even sources of American imports. The shift from west coast to east coast ports could notably shift the balance of domestic freight traffic from rail towards more trucking freight, as rail's cost advantages are greater over very long-distance freight from the west to the east coast.

Those same domestic transportation networks will remain crucial for the resilience of US supply chains, and are

[6] S. Lehman and J. Lack, "Major U.S. Airports Brace for Renewed Traffic Growth with Big Spending Plans", Fitch Ratings, 25 October 2023.

[7] J. Miller and J. Towers, "U.S. Imports Shifting East. Can the Supply Chain Keep Up?", *Railway Age*, 25 March 2024.

coincidentally becoming less resilient as American transport infrastructure continues to age and require replacement or rehabilitation. At key junctures, even single points of failure can cause massive disruptions in American supply chain networks, as recently demonstrated by emergency failures on the I-95 highway near Philadelphia,[8] the recent freight rail derailment near East Palestine, Ohio,[9] and the recent Key Bridge collapse in Baltimore.[10] The supply chain impacts of all three incidences highlight the need for the United States to rehabilitate critical aging transportation infrastructure, and to develop redundancies for key bottlenecks. As discussed in the following section, both of those priorities are incorporated in recent US infrastructure legislation.

Energy Infrastructure. America's energy infrastructure may also be a constraint on re-shoring manufacturing in key industries. New energy intensive manufacturing facilities will need to compete with a booming data center construction sector for tie ins to domestic energy grids. Demand for power in the United States is now forecasted to grow rapidly after decades of very low growth.[11] That demand growth will occur as US energy utilities increasingly incorporate more intermittent renewable energy sources, and will exacerbate challenges with grid reliability.[12]

Mining and Critical Minerals. American mining and critical mineral infrastructure will also need to significantly expand in the coming years to facilitate re-shoring and more

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[8] J. Rogers, "After Philadelphia I-95 Collapse, Buttigieg Weighs Supply Chain, Economic Impact: 'That Is a Lot of America's GDP Moving along That Road'", *MarketWatch*, 13 June 2023.

[9] S. Briscoe, "Ohio Train Derailment Creates Far-Reaching Implications", *Security Management*, 21 February 2023.

[10] R. Lerman et al., "See How the Key Bridge Collapse Will Disrupt the Supply of Cars, Coal and Tofu", *Washington Post*, 27 March 2024.

[11] L. Kearney et al., "US Electric Utilities Brace for Surge in Power Demand from Data Centers", *Reuters*, 10 April 2024.

[12] J. Wilson and Z. Zimmerman, "The Era of Flat Power Demand Is Over", *GridStrategies*, December 2023.

resilient supply chains. This is particularly important because all of the industries targeted by American industrial policy, from renewables to electric vehicles to semiconductors, require significant new mining and critical mineral capacity, and demand for those critical minerals is occurring globally. The International Energy Agency (IEA) forecasts that mining for clean energy materials would need to quadruple globally by 2040 in order to meet the targets included in the Paris Climate Agreement.[13]

Mining capacity within the United States or by its allies would need to grow even further, in part because the US has not significantly invested in domestic mineral production in recent decades. Currently the US imports a majority of critical minerals used in battery production, including 76% of its cobalt, 56% of its nickel, and 100% of its manganese. The scale of current imports and planned growth in key sectors have led many analysts to conclude that reliance on imports from more reliable trade partners, and not just domestic production, will be a necessary part of any American critical mineral strategy.[14]

Biden Administration Re-shoring and Resilient Supply Chain Efforts

The Biden Administration has clearly made supply chain resilience and the promotion of domestic manufacturing key pillars of American industrial policy. This section will first review some of the administration's senior coordinating efforts, along with its recently passed infrastructure and industrial policy legislation.

The Biden Administration first created a Supply Chain Disruptions Task Force in 2021, when pandemic-induced

[13] International Energy Agency (IEA), "The Role of Critical Minerals in Clean Energy Transitions", March 2022.

[14] R. Johnston and C. Vazir, "A Critical Minerals Policy for the United States", Aspen Institute, 20 June 2023.

supply chain bottlenecks were exacerbating high levels of inflation and goods shortages in the United States.[15] That senior-level administrative body would eventually evolve into the Council on Supply Chain Resilience, which includes senior cabinet officials and is co-chaired by the National Security Advisor and the National Economic Advisor.[16] The Council serves as the senior-most coordinating body within the federal government to coordinate a number of supply chain resilience programs and industrial policies.

The Office of the United States Trade Representative (USTR), led by Ambassador Katherine Tai, is another key office in the Biden Administration working to promote supply chain resilience policies. As this chapter was being written, the USTR was soliciting input from the American public on policies to better measure supply chain resilience and to promote supply chain resilience in key industries, such as aerospace, automobiles, clean energy, critical minerals, semiconductors and even textiles. The request for public input further states that:

> The President is using all the tools at his disposal, including new authorities under the CHIPS and Science Act, Inflation Reduction Act, and Bipartisan Infrastructure Law, to incentivize the re-shoring and domestic expansion of critical supply chains. Enduring resilience will require new investments in infrastructure, new incentives to increase the supply of key inputs, and new forms of cooperation with allies and trading partners to prevent and withstand supply chain disruptions and mitigate risks of price spikes and volatility that could contribute to inflationary dynamics.

Other Biden Administration efforts have focused on improving domestic supply chains through improved information sharing. One such initiative was Freight Logistics Optimization Works

[15] L. Weinstock, "Summary of Selected Biden Administration Actions on Supply Chains", Congressional Research Service, 13 May 2022.

[16] The White House, "Readout of the Inaugural Meeting of the White House Council on Supply Chain Resilience", Washington DC, 29 November 2023.

(FLOW), which was launched by the Biden Administration in early 2022.[17] The program aims to recruit US supply chain companies to share data on shipping and logistics, which the federal government can then use to produce aggregate forecasts on domestic freight volumes, for use by all industry participants. The program began publishing data on inland freight hubs for participants to access in early 2024.[18]

However, the Biden Administration's most important initiatives impacting manufacturing supply chains came from three major pieces of infrastructure and industrial policy legislation. Those were the Infrastructure Investment and Jobs Act (IIJA), the Inflation Reduction Act (IRA), and the CHIPS and Science Act.

Infrastructure Legislation. The US passed the IIJA in 2021 to provide a generational federal investment in American infrastructure. The legislation authorized $1.2 trillion in federal infrastructure spending, including $550 million for new investment programs. The majority of that funding is dedicated to the transportation sector, including a total of $40 billion for bridges alone.[19]

While much of the IIJA's funding is formula-based, in which major spending decisions are made by the states, the IIJA is also noteworthy because a historically large proportion will be directly invested by the federal government. One formula fund example is the National Highway Freight Program, which was allocated $7.15 billion in the IIJA. The program includes formula grants to the states for highway projects that improve freight movement. In discretionary funds, the legislation includes more than $100 billion in discretionary grants across more than 20 programs for the Department of Transportation

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[17] The White House, "Fact Sheet: Biden-Harris Administration Announces New Initiative to Improve Supply Chain Data Flow", Washington DC, 15 March 2022.

[18] US Department of Transportation, "Biden-Harris Administration Announces New Milestone in First-of-Its-Kind Supply Chain Initiative", 20 March 2024.

[19] The White House, "Guidebook to the Bipartisan Infrastructure Law", Washington DC, May 2022.

alone. Some of the programs, such as the Nationally Significant Freight and Highway Project (INFRA) grant program, are competitive grants that target major infrastructure projects that eliminate freight bottlenecks or meet other transportation priorities. These programs afford the Biden Administration significant discretion in how it selects projects for federal grants.[20]

The IIJA also includes a historic amount of funding for transit and intercity rail projects. Though the vast majority of this funding is dedicated to passenger rail in particular, several programs also include funding to improve the safety or reliability of the nation's freight rail network, including the Consolidated Rail Infrastructure and Safety Improvement Grant program. The legislation also includes more than $16 billion in funding to maintain, rehabilitate or improve the reliability of ports and inland waterways infrastructure. $2.25 billion of that funding will be allocated via the Port Infrastructure Development Program. Late last year, the Biden Administration awarded more than $653 million in grants to 41 different port improvement projects, including major expansion projects at the port of Long Beach, California and the port of Newark, New Jersey.[21]

Industrial Policy Legislation. The Biden Administration's major industrial policy legislation in the IRA and CHIPS Act leverages other policy tools to create strong incentives for re-shoring manufacturing in their respective sectors. The CHIPS Act does so directly, with more than $60 billion in subsidies for domestic manufacturing sectors across a range of policy tools.[22] The IRA likewise includes many demand-driving subsidies for renewable energy and electric vehicle sectors, but

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[20] U.S. Government Accountability Office, "DOT Should Improve Transparency in the Infrastructure for Rebuilding America Program", January 2024.

[21] U.S. Department of Transportation, "Biden-Harris Administration Invests More Than $653 Million in Ports to Strengthen American Supply Chains", 3 November 2023.

[22] D. Kamin and R. Kysar, "The Perils of the New Industrial Policy", *Foreign Affairs*, 18 April 2023.

the Biden Administration is explicitly limiting their application to products that are produced and manufactured in the United States.

The Biden Admin's industrial policy efforts in the IRA even managed to court a dispute filing at the World Trade Organization. The dispute was filed by China in March 2024.[23] The consultation request points out that the IRA Clean Vehicle Credits will not apply to vehicles with critical minerals "extracted, processed, or recycled" by a "foreign entity of concern" which includes entities controlled by the Chinese government. The request also claims that several renewable energy tax credits in the IRA are increased by 10% if certain domestic content requirements are satisfied. The request states that

> subsidies that are contingent on the use of domestic over imported goods or that otherwise discriminate against imported goods, remain prohibited and threaten to undermine international cooperation on reducing and mitigating the effects of climate change.

Roadblocks to Re-shoring

Despite these great legislative accomplishments, the United States still faces significant challenges particular to re-shoring manufacturing and supply chains. This is because American development policies remain largely unchanged by recent legislation. It is extremely difficult to permit and develop new transportation, energy, or mining infrastructure in the United States, and manufacturing facilities directly supported by recent federal industrial policies will also be required to complete a similar federal permitting process as a major infrastructure project. These constraints on infrastructure

[23] World Trade Organization (WTO), "United States - Certain Tax Credits Under the Inflation Reduction Act: Request for Consultations by China", 28 March 2024.

growth will limit or at the very least delay the pace of American re-shoring of manufacturing industries. It will also direct new domestic manufacturing investment towards regions in which there is already capacity in existing transportation and energy infrastructure to accommodate growth.

Infrastructure development in the United States is governed by many regulations, but the most important is the National Environmental Policy Act of 1970 (NEPA). NEPA requires federal agencies to produce an environmental study prior to undertaking an action that will have a significant impact on the environment, such as a major infrastructure project. The study is called an Environmental Impact Statement (EIS) for those projects.[24] For an infrastructure project with significant environmental impacts, the administrative process under NEPA includes the development of a large environmental study, which includes a public notice and comment period to incorporate feedback from stakeholders and the public. Most importantly, however, NEPA also gives impacted citizens or groups a right of action to challenge environmental studies in federal court. If a judge concludes that the project environmental study is insufficient, they may enjoin the project in question and require further environmental study.[25] Due to the way case law governing NEPA has evolved, projects are often challenged and potentially enjoined over procedural deficiencies in the study, such as the omission of an environmental impact from the study, as opposed to substantive disagreements, such as a particular environmental assumption or conclusion in the study.[26]

Development policy in the United States thus combines an open-ended administrative requirement to study all "environmental impacts" of a project, with a broadly distributed

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[24] D.R. Mandelker, *NEPA Law and Litigation*, 2nd Edition, Clark Boardman Callaghan, 2018.

[25] Ibid.

[26] M. Bennon and D. Wilson, "NEPA Litigation Over Large Energy and Transport Infrastructure Projects", *Environmental Law Reporter* , vol. 53, no. 10, October 2023.

right of action for citizens or stakeholders to intervene to challenge projects in court on the grounds that agencies have not adequately met that open-ended administrative requirement. That combination makes the development of environmentally impactful infrastructure projects uniquely difficult, slow and uncertain in the United States today.

The NEPA process described above applies only to federal actions with significant environmental impacts, rather than private manufacturing projects. In addition, the vast majority of federal projects do not meet the threshold of "significant" environmental impacts and tend to have a much shorter permitting process.[27] Therefore, the NEPA process would primarily hinder those large infrastructure projects that expand transportation or energy networks or expand domestic critical mineral supply.

However, that same development process may uniquely impact the very facilities that the Biden Administration is trying to promote via industrial policy. Because the administration's industrial policies are promoting manufacturing in some sectors with direct government grants and subsidies (notably with the CHIPS Act), those manufacturing facilities that receive direct federal support will also be subject to the NEPA permitting process. To date, the US Congress has not passed legislation exempting these manufacturing facilities from the NEPA process.[28]

These development policies matter, and their impacts in practice differ widely between sectors. For large transportation infrastructure projects with significant environmental impacts, the NEPA process tends to result in extremely long permit durations. An EIS completed by the US Federal Highway Administration (FHWA), the majority of which are for highway or highway improvement projects, takes more than 7 years to complete on average.[29]

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[27] D.E. Adelman and R.L. Glicksman, "Presidential and Judicial Politics in Environmental Litigation", *Arizona State Law Review*, 50, no. 3, 2018.

[28] J. Calma, "How the next Generation of Semiconductor Factories Kicked up a Fight over Environmental Review", *The Verge*, 13 October 2023.

[29] Council on Environmental Quality, "Environmental Impact Statement

Energy infrastructure projects face similar challenges during the NEPA process when they are required to complete an EIS. In those cases, they tend to have shorter permit timelines on average but also have relatively high rates of litigation challenging the project environmental study, and this occurs for projects associated with fossil fuels, such as pipelines, as well as for renewable energy projects such as wind farms and transmission lines.[30] Many energy generation projects are advantaged because they are typically privately financed in the United States and, absent other federal involvement, would not necessarily be required to complete the NEPA process. However, other key projects such as interregional transmission lines often require the NEPA process and face the associated challenges. The coincidence of the re-shoring drive with an ongoing datacenter construction boom and the energy transition are placing considerable stress on the US energy grid. Interconnection queues for new energy projects have increased significantly in recent years, with an average wait time of 5 years at the end of 2022 compared to less than two years in 2008.[31]

There has been considerable press and some political momentum[32] around implementing permitting reform during the Biden Administration, but very little has been accomplished. The IIJA itself includes some permitting reforms, including a One Federal Decision policy requiring greater coordination among federal agencies during NEPA administration. In June 2023, Congress also passed some additional permitting reforms as part of the Fiscal Responsibility Act, including a clarification that agencies must study "reasonably foreseeable" environmental

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Timelines (2010-2017)", Washington DC, Executive Office of the President, 2018.

[30] Bennon and Wilson (2023).

[31] J. Rand et al., "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2022", Lawrence Berkeley National Laboratory, April 2023.

[32] R. Frazin, "Senate Rejects Manchin's Energy Permitting Amendment to Defense Bill", *The Hill*, 15 December 2022.

impacts in their studies, but none of these legislative changes amount to significant reform of the development process.

These policy impediments to re-shoring could theoretically change, but there are significant political impediments to major federal permitting reform in the United States. Environmental and conservation groups generally oppose the reforms, and are an important constituency of the Democratic Party. Currently, congressional Democrats appear open to reforms that would enable streamlined permitting or exemptions specifically for renewable energy or transmission infrastructure. However, Republicans in Congress want broader permitting reforms, and have thus resisted proposals for sector-specific changes. Because of this impasse, permitting reform negotiations have been ongoing in Congress for years with very little progress.[33]

America's Friend-shoring Future

These constraints on infrastructure expansion are in addition to the many other state, local and other federal regulations that exist in the United States today that will slow down and increase the costs of new domestic manufacturing facilities. The vast majority of these regulatory barriers and opportunities for stakeholder intervention did not exist when America's domestic manufacturing base and supply chains were originally built. Re-shoring American manufacturing will thus be slower, more constrained by transportation and energy networks, and much more costly for firms, irrespective of the industrial policy or tax incentives available today.

For these reasons, the diversification of American manufacturing and supply chains outside of China will very likely be heavily reliant on friend-shoring, as opposed to re-shoring. For transportation infrastructure, a major shift will occur as supply chains shift from west coast to east coast

[33] C. McGeady, "The State of Play in Permitting Reform", *Center for Strategic & International Studies*, 24 May 2023.

American ports. The domestic manufacturing growth which does occur will likely flow to regions with excess transportation and energy capacity, available skilled labor, and relatively relaxed state and local development regulations.

To be sure, there are many other impediments to domestic manufacturing growth in the United States, from relatively high labor costs to a lack of high skilled immigration and others. Industrial policy incentives and other reforms can certainly help bring manufacturing jobs back to the United States, but such a shift would also require significant growth in America's domestic transportation and energy infrastructure. The most important constraints on American development are the policies in place that constrain American development.

11. How the Future of Trade, Logistics and the Energy Transition Benefit the Gulf Arab States?

Karen E. Young

The geopolitics of the current age are more than a great power competition between the United States and China; it is a false narrative to limit the role of the developing economies of the Global South to aligning themselves with one side or the other. While we may indeed be in some inter-regnum period of heightened risk of conflict, there are broader economic trends that may be more important in the shaping of our future global political economy. And in this new global economy, the specific role played by developing countries will set the pace and geography of trade as well as relationships between new trade partners and intermediaries. New trade routes, investment partnerships, energy demand and adaptation of technology within and among developing economies will shape new political relationships and build multiple new centers of economic power. The Gulf is not between the US and China, but at the center of new trade routes and a changing energy demand landscape with new manufacturing locales, positioning the Gulf Arab states of the Arabian Peninsula (most notably two: Saudi Arabia and the United Arab Emirates) as a burgeoning logistics hub and artery of the global economy. There is no fixed center of trade, but rather an eastward shift of intensity.

Gulf Positionality in a New Global Trade Environment

Understanding Gulf positionality in a new global trade environment requires a framing of emerging market economy growth and connectivity. The New Silk Road is one way of describing this geography and burgeoning economic regrouping. Stretching from East Asia to Morocco in North Africa, the New Silk Road grouping encompasses 50 countries and 4.9 billion people, including eight out of the world's top 20 economies. Its share of global gross domestic product (GDP) has risen to 40%, and the Oliver Wyman consultancy estimates this will reach 48% by 2040.[1] Global trade is more concentrated among emerging market economies. This transition has been under way for some time. Since 2010, emerging markets have been a global source of export activity, accounting for nearly 45% of global exports compared with only 25% in 1996 and this growth is not driven solely by China, as researchers at the Federal Reserve demonstrate.[2] Integration into global financial markets is also part of the new geography of trade, and a point of connection at which the Gulf states excel. New Silk Road firms, or those based across emerging markets of Asia and the Middle East, account for 221 of *Fortune 500* firms.[3]

The New Silk Road defines the complexity of global supply chains, including the flexibility created by a China+1 trend, whereby relocating manufacturing out of China has the knock-on effect of creating opportunities for other developing countries in Asia, as well as external regional investors. The use of financial markets and investment vehicles builds a web connecting capital within emerging market economies. Because

[1] A. Alfalasi and B. Simpfendorfer, The New Silk Road: Growth, Connection and Opportunity, Oliver Wyman, 2024.

[2] R. Reyes-Heroles, S. Trailberman, and E. Van Leemput, "Emerging Markets and the New Geography of Trade: The Effects of Rising Trade Barriers", International Finance Discussion Papers 1278, 2020, pp. 4-5.

[3] Alfalasi and Simpfendorfer (2024).

so much capital is concentrated in the Gulf, there are unique opportunities for Gulf state investment vehicles, many with mandates to invest more in Asia and to allocate funds to clean energy projects.

The strength of the grouping will depend on its ability to incorporate more technology in its manufacturing for renewable energy supply chains. For example, India's ability to ramp up its production of solar panels will give it preferential access to the kinds of firms growing in the Gulf as well to developed markets in North America and Europe. This will allow it to expand solar power production at home and through its state-owned firms building solar power plants across Africa and West Asia. In this sense, trade and investment are joining forces in the Gulf to deploy at scale across a wide geography of increasing energy demand and consumer product demand. This makes the Gulf a hub for both capital and logistics. Its strengths lie in four factors and trendlines discussed below, related to: 1) geography, 2) access to capital and ability to deploy it swiftly, 3) fortuitous access to sites of emerging growth, and 4) a deep expertise in energy product delivery that will be helpful during an energy transition. The weaknesses of the Gulf are entirely political, in that its geographic and political entrepot position depends on access to the US capital markets and defense umbrella, in conjunction with access to trade and consumer markets across emerging Asia and Africa – and all this while maintaining its special relationship with China and India.

The domestic political imperative to embrace this eastward shift and to mobilize state capital in investment abroad and trade infrastructure at home is quite simple. The Gulf oil and gas exporters face an uphill battle to build their non-carbon energy sectors, increase local manufacturing and grow non-oil GDP. The IMF reports why that diversification effort is so challenging.[4] History tells us that a decline in extractive activity

[4] D. Mesa Puyo, A. Panton, T. Sridhar, M. Stuermer, C. Ungerer, and A. Tianbo Zhang, "Staff Climate Notes: Key Challenges Faced by Fossil Fuel Exporters during the Energy Transition", International Monetary Fund, Washington DC, 2024.

weakens real GDP and trade performance, even in new industry. Researchers plotted local projections based on 35 past episodes of sustained, exogenous declines in extraction for 13 minerals (oil, gas, coal, metals) and 122 countries since 1950, finding that declines in extractive activity can have persistent negative effects on real GDP and the trade balance.[5] Periods when there are major resource extraction declines can weaken growth by 10% on impact and 40% by the tenth year on average, reducing private and public consumption and lowering investment. Restricted monetary policy in the GCC states, along with public investment may help buffer some of these expected effects, but the comparable case experience is not encouraging. Increases in public investment in trade infrastructure and connectivity to where both consumer demand and economic growth rates will be higher are imperative strategies for these states to pursue in tandem with or in advance of any decline in extractive industry.

Gulf Infrastructure on Call

Indeed, the places where we find the largest investment and growth in trade infrastructure, especially ports, tend to be in Asia and the Gulf. *MEED* reports that current global port infrastructure investment projects in early 2024 (embracing the early pre-planning stages of announcement and study, through to execution) stand at a combined value of $497 billion.[6] Southeast Asia has the highest share of the pipeline value, standing at $84.5 billion, followed by the Middle East and North Africa region at $73.2 billion and South Asia at $73.1 billion. New port construction in the GCC in the last year includes plans to build a new terminal at Ras Al Khaimah in the UAE, with a contract awarded to China Harbour Engineering

[5] R. Bems, L. Boehnert, A. Pescatori, and M. Stuermer, "Economic Consequences of Large Extraction Declines: Lessons for the Green Transition", IMF Working Paper 2023/097, International Monetary Fund, Washington, DC, 2023.
[6] "Global Economy Needs More Port Infrastructure", *Meed*, 3 March 2024.

(Chec). In March 2024, Bahri Logistics also began building a new logistics and distribution center in Jeddah Islamic Port. AD Ports Group (Abu Dhabi government-owned) signed an agreement in partnership with the Red Sea Ports in Egypt. Ports in the Gulf (and the Middle East as a whole) regularly rank as the most efficient in the world in World Bank and S&P Global Market Intelligence container port performance indices.[7] The port connections between the Gulf and China include contracting services as well as trade. Chinese contractors frequently win awards for port expansions and for collaborations or joint ventures in industrial zones around Gulf ports, and that industrial activity is usually related to the energy sector (e.g., refineries, crude or refined product storage) or the transport of energy and new energy products (e.g., green steel, critical minerals for Electric Vehicle (EV) production).

To this end, the GCC states currently own, or are operating, building and investing in the following set of regional[8] port infrastructures:

1. Port of Jebel Ali (UAE). Owned by Government of Dubai, operated by DP World.
2. Port of Salalah (Oman). Owned by Government of Oman, operated by APM Terminals (subsidiary of Maersk Group).
3. Port of Djibouti (Djibouti). Owned by Government of Djibouti, formerly operated by DP World and, after a government takeover (2018), now operated by Djibouti Ports and Free Zones Authority.
4. Port of Aden (Yemen). Owned by the Government of Yemen, operated by multiple firms, including DP World and China Merchants Port Holdings and local Yemeni authorities.

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[7] "Middle East container ports are the most efficient in the world", World Bank Group, 25 May 2022.

[8] There are important expansions of Gulf port operators outside of the Gulf region, including East and West coasts of Africa. See work by E. Ardemagni, "One Port, One Node: The Emirati Geostrategic Road to Africa", ISPI, 2023.

5. Port of Berbera (Somaliland, Somalia), owned by the Government of Somaliland and operated by DP World.
6. Port of Aqaba (Jordan), owned by the Government of Jordan, operated by Aqaba Development Corporation (ADC), but recently AD Ports Group (Abu Dhabi government-owned) and ADC signed a joint venture (51% stake held by AD Ports Group subsidiary Maqta Gateway) to create an operating company Maqta Ayla to streamline operations at the port and in road trade to Jordan.[9]
7. Port of Duqm (Oman) is owned by the Government of Oman and operated by the Port of Duqm Company, a government entity. There is investment in the special economic zone at Duqm, including a commitment to invest $3.7 billion in development over 30 years by China's Oman Wanfang.[10] This has been slow to materialize. However, an investment by Kuwait to build an oil refinery in Duqm has already paid dividends given the refinery's strategic location outside of both the Red Sea and Strait of Hormuz, away from recent conflict in the region.[11]
8. Jeddah Islamic Port (JIP) is one of the oldest ports in Saudi Arabia, recently deepened and expanded to more than double container capacity to 6.2 million containers spread over 11 platforms.[12] The terminal facility is operated by DP World.
9. Ras Al-Khair Port (Saudi Arabia). Located in the Eastern Province of Saudi Arabia is part of an industrial zone

[9] A. Sambidge, "Ad ports deal to transform Jordan's Aqaba", *Arabian Gulf Business Insight*, 16 February 2024.

[10] J. Aguinaldo, "Chinese investor mobilises for Duqm Project", *MEED*, 4 April 2017.

[11] A.D. Paola, "Duqm oil refinery cranks up output as fuel cargoes avoid Red Sea", *Bloomberg*, 8 February 2024.

[12] A. Hammond, "Expansion of Jeddah Islamic Port complete", *Arabian Gulf Business Insight*,16 February 2024.

serving the Ma'aden phosphate and aluminum plants, among other facilities like the Shanghai-based Baoshan Iron and Steel Co. Recently, $4 billion was invested in the Ras Al-Khair special economic zone to manufacture steel plates.[13]

10. Dhiba Port (Saudi Arabia). Located near the NEOM project and its Oxygon industrial zone on the Red Sea coast, this port is being expanded with plans to handle 3.5-4-million-ton equivalent units (TEUs) by 2030 (for comparison, Jebel Ali has a capacity over 19 million TEUs.)[14] The port is near the Jordanian border and could play an instrumental role in broader MENA connectivity for Saudi exports, in some ways in an alternative route proposed by the India-Middle East Economic Corridor (IMEC) (discussed below).
11. Yanbu Commercial Port (Saudi Arabia). Also, located on the Red Sea coast in the Madinah region, the port is undergoing expansion of its berths, terminals and ability to accommodate larger vessels.
12. Ras al Khaimah (UAE) Saqr Port and the RAK Free Zone and Maritime Zone are all part of RAK Ports. An expansion in 2019 added two deep water Capesize berths at Saqr Port with annual capacity of 95 million tons, making this one of the largest dry bulk ports in the world. A 2024 contract awarded to China Harbor Engineering Company (Chec) will cover a new steel sheet pile wharf, dredging and widening of the channel.[15]
13. Abu Dhabi Ports Group (UAE) operates 10 ports in the UAE, including the Khalifa Port in Abu Dhabi,

[13] "China's Baoshan Iron and Steel Co. invests $4bn in Ras al-Khair Economic Zone", *Arab News*, 30 May 2023.

[14] V. Nereim, "Saudi prince's 'neom' to expand port to rival region's biggest", *Bloomberg*, 25 November 2021.

[15] Y. Iqbal, "Chinese contractor wins Ras Al khaimah port upgrade", *MEED*, 5 March 2024. t

in a set of commercial ports and terminals, along with community ports and tourist cruise terminals. Beyond east-west trade, the Khalifa Port and economic trade zone (KEZAD) are home to industrial processing, including a new agreement with Titan to import lithium mined in Zimbabwe to be processed into battery-grade lithium carbonate and lithium hydroxide for battery manufacturers and electric vehicle original equipment manufacturers in KEZAD.[16]

14. Abu Dhabi Ports Group also wholly owns the Port of Fujairah in the northern UAE, which is the third largest bunkering hub in the world, with a crude oil product storage capacity in excess of 10 million cubic meters.[17]

Gulf Rail

There has been considerable interest and speculation about the possibilities of a more inter-connected rail system to boost intraregional trade and to support burgeoning efforts to create east-west trade corridors from India to the Mediterranean and on to Europe. The GCC rail project has been a point of discussion for over a decade, when the Gulf Railway project was approved at the thirtieth GCC summit in Kuwait City in December 2009, with a completion date set for 2018. The steep decline in oil prices in 2016 created the first delay in project awards and then, in 2017, the GCC dispute (which officially took place between June 2017 - January 2021) between the UAE, Saudi Arabia, Bahrain and Egypt and neighboring Qatar disrupted all chances of regional economic integration. With the Al Ula agreement signed in January 2021, the GCC secretariat effectively restarted the project, though the six member states are at different stages of new tenders and awards. GCC leaders

[16] Y. Iqbal, "Titan to establish $1.4bn KEZAD Lithium Plant", *MEED*, 14 February 2024.

[17] "About Us - Trade Logistics Hub. Fujairah Terminals", 16 March 2023.

approved the establishment of the GCC Rail Authority in January 2022. That same year, Oman and the UAE established the Oman-Etihad Rail Company to implement a 303-kilometer network, supported by an investment from Mubadala. The utility of the rail network lies in energy and logistics supply chains rather than necessarily for passengers or consumer products. The Oman-Etihad Rail Company signed a memorandum of understanding (MoU) with Brazilian mining company Vale to explore the possibility of using rail to transport iron ore and its derivatives between Oman and the UAE, connecting Vale's industrial complex in Oman's Sohar Port and Freezone and a planned hub in Abu Dhabi. Vale is the same firm in which the Saudi PIF and state mining company Maaden recently acquired a 10% stake. Oman and Saudi Arabia plan to establish a railway link connecting Duqm with Riyadh through the Ibri border, for a planned economic zone in the Al-Dhahirah area.

Inside Saudi Arabia, the land bridge project has potential for considerable efficiencies and expansion of trade networks. As Saudi Arabia plans to integrate rail with sea and dry ports, the $7 billion Saudi land bridge rail project recently issued a call for project management tenders, with contracts awarded to US-based Hill International, Italy's Italferr and Spain's Sener in December 2023. The Saudi China land bridge consortium, a joint venture between Saudi Railway Company and China Civil Engineering Construction, reported in November 2023 that it was at the final stages of negotiation with contractors for the project.[18] When finished, the six-line railway will connect Jubail and Damman to Jeddah and Yanbu, running east to west across Saudi Arabia with 1,500 km of rail lines. The Red Sea ports of Saudi Arabia have been somewhat shielded by recent attacks by the Houthis on sea transit, as they are based farther north. East-west transit avoids the Strait of Hormuz and has the advantage of being able to use the Saudi port networks on the Red Sea coast.

[18] C. Foreman, "Firms win Saudi landbridge", *MEED*, 7 December 2023.

India-Middle East Economic Corridor[19]

At the September 2023 G20 meeting, the host country India along with the United States, the European Union, France, Germany, Italy, Saudi Arabia and the United Arab Emirates signed a memorandum of understanding, a non-binding commitment, to work towards building two separate "corridors", essentially envisioning a political line that is connected by physical infrastructure – some new and some existing, or already under construction. The east corridor envisions connecting India to the Arabian Gulf and the northern corridor connecting the Arabian Gulf to Europe. Its most visible infrastructure project is an old-fashioned railway operating as a ship-to-rail transit network enabling goods and services to transit to, from, and between India, the UAE, Saudi Arabia, Jordan, Israel, and Europe. More importantly the line can also be used for other purposes, including the laying of cable for electricity and digital connectivity and, most crucially, as a conduit for clean hydrogen export from the Gulf to Europe.

The IMEC is part of a wider collaboration among G7 governments, international financial institutions and private (mostly US) infrastructure investors. In a belated policy response to China's BRI, the US government and partners in the G7 announced a Partnership for Global Infrastructure and Investment (PGII) in May of 2023.[20] The intention is to politically support more blended finance for clean power, transport, health and climate resilient infrastructure in low and middle-income countries. The IMEC does not neatly fit into the PGII initiatives either, as it is not an accelerator of clean energy finance and the countries it connects are not all low or middle-income. The IMEC does serve broader energy security goals for European nations and allows the United

[19] This passage draws from K. Young, "All you need to know about the India-Middle East Economic Corridor", *Al Majalla*, 4 November 2023.

[20] "Fact sheet: Partnership for global infrastructure and investment at the G7 summit", *The White House*, 20 May 2023.

States to advance a national security goal in supporting regional economic integration by knitting together its strategic partners Israel and Saudi Arabia, at least by rail.

The IMEC is a political imagining of balance by the West, under a multipolar system that mainly adds states to its side of the balance sheet in a future conflict with China. In reality, the IMEC provides something for all, even China. The Gulf, particularly the UAE, is already the most important re-export source of Chinese goods in the region. An additional corridor by land would only facilitate that existing capacity from Jebel Ali. This begs the question: is the new route is any faster, cheaper, or safer than existing sea routes? It still has to navigate the Strait of Hormuz and depends on another sensitive location at Israel's Haifa, a port now managed by an Indian conglomerate that is backed by Emirati state investment.[21] The UAE is most advantaged in cementing its trade ties with India, and growing new investments in strategic infrastructure assets through Israel, the Eastern Mediterranean and on to Europe. Despite the GCC rail network plan coming back on line, Oman is not a signatory of the IMEC memorandum of understanding and its new port development on the Arabian Sea at Duqm, which is much closer to India, will not be part of the corridor

The Gulf Logistics Thesis

The Gulf central logistics thesis rests on four factors and trends:

1. A central geographical location. The location of GCC countries is an advantage because transporting renewable energy over long distances, whether in the form of electricity or hydrogen, is costly. As the cost of producing renewable electricity and hydrogen continues to decline, the transportation share of the overall cost structure will increase. The GCC countries offer

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[21] F. Elbahrawy and B. Shrivastava, "Adani enterprises FPO: Abu Dhabi's IHC invests $400 million in Adani Share Offer", *Bloomberg*, 30 January 2023.

comparatively easy access to large import markets in both Europe and Asia, as well as to developing markets such as those within Africa. The Gulf states benefit not only in terms of the shifts in inter-Asian trade, occurring as manufacturing moves from China into other ASEAN countries, but also in the Gulf's proximity to India. As higher tech manufacturing also moves to India, the evolution of supply chains in renewable energy, especially in EV manufacturing and solar panel components, will benefit Gulf solar companies expanding abroad and new car manufacturing efforts at home, as well as intermediary positions in export to Africa and beyond. As a center of a new energy market, which encompasses products from electricity transmission (from solar and nuclear power) and green and blue hydrogen fuels to new energy sources, the Gulf has a key advantage.

2. The Gulf states benefit due to their geographic location as an intermediary of trade between high growth areas in Africa and the Middle East and Asia, but they may derive as much or more advantage from their role as financial intermediaries and investors in infrastructure, both at home and abroad. While the cost of capital is rising under global inflationary pressures, Gulf governments and their state investment vehicles have many more institutions on hand to access capital markets at favorable interest rates than other emerging market economies. They can leverage state firms to borrow against and can issue partial privatizations to raise capital; this strategy has been essential to Saudi Arabia's Vision 2030 objectives, including raising the capital needed to build domestic infrastructure for trade networks. GCC states can deploy capital at scale for infrastructure for the energy transition and in transport systems. The IMF predicts that Southeast Asia, South Asia, and Sub-Saharan Africa will be central to future trade growth. It expects China's influence on global trade growth to wane as

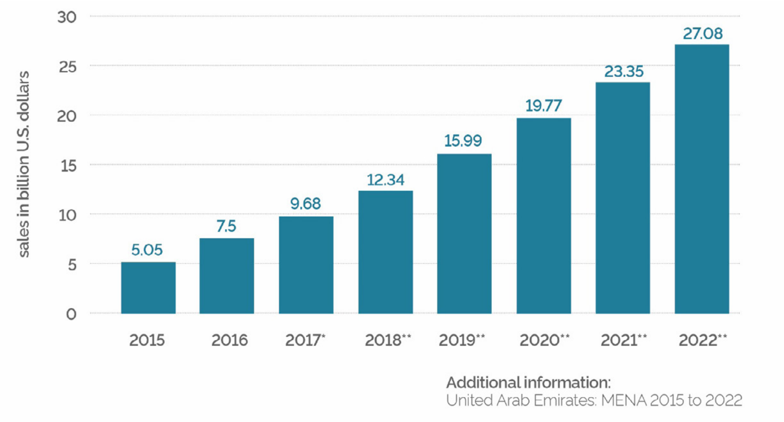
trade becomes more diversified across many countries. By 2026, it is expected that emerging economies will account for 45% of trade growth. The GCC states are best positioned as investors and operators of major infrastructure projects in these growth areas – from ports to power plants.

3. Trade growth and density is changing with e-commerce trends, demand for sustainable materials like green steel, materials for low carbon products like EVs, and an increase in the volume of trade between China and ASEAN and Silk Road countries. E-commerce trends across developing economies will require additional air cargo. Gulf state carriers are capitalized and expanding. GCC investment can also benefit from the relocation of manufacturing from China into other Asian locations, creating new co-investment opportunities with Chinese firms and new export routes by sea and air cargo for Gulf carriers. Air cargo is a growing market and the ability to finance and run state-owned carriers is a critical advantage. The growing trend of e-commerce, especially in apparel and household goods from Chinese discount retailers, is transforming the air cargo sector. According to the International Air Transport Association (IATA), one in five parcels currently transported has been purchased online, and the figure is set to grow to one in three by 2027.[22] E-commerce within the GCC is also booming, as traditional point-of-sale retail is increasingly shared by online purchases and delivery. In the UAE, the Ministry of Economy finds just 4.2% of retail is e-commerce, the largest in the MENA region, with clear room for growth.[23]

[22] C. Goldstone, "A 'tsunami of e-commerce growth' on course for Air Cargo", *The Loadstar*, 14 March 2024.

[23] UAE Ministry of Economy, "Investing in Logistics in the UAE".

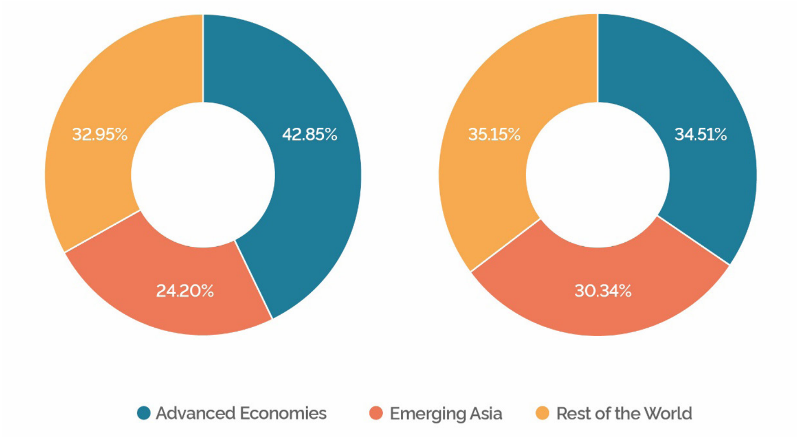
FIG. 11.1 – VALUE OF E-COMMERCE SALES IN THE UNITED ARAB EMIRATES FROM 2015 TO 2022 (IN BILLION US DOLLARS)



Source: DED (Dubai), Statista, 2021

As China's lower-end industrial sectors relocate towards ASEAN countries, there are opportunities for more labor-intensive manufacturing for leather, textiles, ceramics and glass along with companies engaged in solar, electric vehicles and lithium battery assembly processing. And while countries like Vietnam, Thailand and Indonesia benefit, other countries such as Morocco, Jordan and Egypt, as well as India, also benefit as competitive labor sites. This shift in the sites of consumption and the sites of manufacturing and assembly, is bringing rapid change for Gulf trade and investment partners. It is an emerging markets story, but also a story of geopolitics and sound national investment strategy.

FIG. 11.2 – SHARE OF TOTAL GULF TRADE WITH ADVANCED ECONOMIES, ASIA, AND THE REST OF THE WORLD, 2010 AND 2022 (%)



Source: Asia House (2023) *The Middle East Pivot to Asia*.

The basic long-term growth prospects for Gulf-Asia trade are robust. In the shorter term, the transport of goods to and from China via air, rail and sea continues to grow, driven by Chinese e-commerce sites specializing in fast fashion and discount retail. As China increases its trade with ASEAN and its New Silk Road partners, the demand for logistics increases. Trade will increase as Asia's economies and middle-class populations, with their attendant demand for energy, expand over the next decade. The Gulf state's efforts to diversify their economies and develop non-oil sectors, especially in sustainability and technology, will further drive cooperation. Though the oil and gas trade dominates growth between the Gulf and Asia at present, the expansion extends beyond oil. Non-oil sectors, particularly technology sectors that are vital for the Gulf's economic diversification and digitalization, have played a significant role.

4. Dominating the energy business. The Gulf states are best positioned to continue oil and gas production while at the same time leading investment and innovation in renewable energy production, technology and export as well as renewable project development on a wide inter-regional scale. This benefits them across emerging market economies, complementing their goal to become partner investors in clean energy policy incentives, like the Partnership to Accelerate Clean Energy (PACE) between the UAE and the United States.[24]

Conclusion

The Gulf is central to a new global trade phenomenon, which will be concentrated in nodes. It will be flexible and in a state of flux, as manufacturing, industrial policy and trade barriers for geopolitical concerns shift, align, and re-align. As demand for new energy increases, new opportunities for products, manufacture and transit will arise, but most of the change will happen within emerging market economies. The acceleration and pace of clean energy demand will be difficult to predict, allowing some leeway for legacy energy exports. Gulf state investments in domestic infrastructure, as well as co-investments in their near neighbors, will hasten their dominance in trade routes and materials, including critical minerals, and solar power deployment, alongside new energy products like green steel and green and/or blue hydrogen. The Gulf stands to benefit as one center of these new trade routes, positioning the Gulf Arab states of the Arabian Peninsula as a burgeoning logistics hub and artery of the global economy.

[24] "Fact sheet: U.S.-UAE Partnership to accelerate transition to clean energy (PACE)", The White House, 1 November 2022.

12. MENA-Europe Value Chain Integration in the Era of Green Transition

Michael Tanchum*

As global supply chains continue to unwind, the maintenance of a prosperous and green Europe will increasingly depend on European Union (EU) Member States achieving green value-chain integration with the nations of the Middle East and North Africa (MENA) region. The greater availability of affordable labor and energy in the MENA region has prompted the relocation of manufacturing and agri-food production to MENA for export to European end-markets. This nearshoring trend has developed most prominently in Morocco,[1] where business conditions are more conducive. The imminent advent of the MENA region as a major producer and exporter of renewable power will greatly accelerate the integration of MENA-to-Europe green-manufacturing value chains. Value chains based on renewable energy will take the form of exports of green energy, intermediate agri-food and industrial manufacturing inputs produced using renewable energy, and green finished products. The rise of the EU's Mediterranean shore as the landfall for these MENA-to-Europe green value chains is not geographically pre-ordained. Despite the relative increases in container traffic witnessed by most of the EU's Mediterranean ports at the onset of the decade compared to

* Prof. Tanchum would like to thank Rocco Schwefel for his research assistance.

[1] "Europe–Africa Connectivity Outlook 2021: Post-Covid-19 Challenges and Strategic Opportunities", Istituto Affari Internazionali (IAI), 10 May 2021.

northern EU ports,[2] this study's primary finding is that, so far, the major northern European ports are positioning themselves more effectively to be the European hub for MENA-to-Europe green-manufacturing value chains.

The efforts of northern European ports and closely located industries to promote the import of renewable energy, such as green hydrogen in the form of seaborne shipments of green ammonia, has been a major contributing factor to this trend. The MENA region's four leading actors in green value-chain integration are Morocco, the United Arab Emirates (UAE), Saudi Arabia and Egypt. The Netherlands and Germany have become the leading European partners for these MENA countries to ship energy in the form of seaborne ammonia. These arrangements have had spillover effects for the export of intermediate products made in the MENA region, using renewable energy. Italy, whose geographical location in the heart of Mediterranean basin should make it Europe's primary Mediterranean conduit for receiving MENA-produced green ammonia, has concentrated on developing trans-Mediterranean pipeline imports of hydrogen from Algeria via Tunisia. While this report raises questions about the feasibility of the undersea pipeline transportation of hydrogen on technical, commercial and environmental grounds, Italy's emphasis on pipeline imports leaves little room for engagement with the four leading MENA green-energy exporters. Rome's January 2024 decision to allocate funds for a feasibility study to explore the creation of a green-hydrogen corridor between Morocco and the Port of Trieste is an important step in the right direction.[3] Italy is a late entrant into the development of green-ammonia terminals, and Rome needs to act more vigorously to facilitate the

[2] M. Deandreis, A. Panaro, and O. Ferrara, "The Role of Shipping and Logistics for the Fluidity of Global Value Chains. New Opportunities in the Euro-Mediterranean Region", in F. Botti (ed.), *Euro–Mediterranean Economic Cooperation in the Age of Deglobalisation,* Istituto Affari Internazionali, IAI, 14 November 2022.

[3] M. Simpara, "Morocco to Fuel European Energy Hub: Italy Backs Green Hydrogen Corridor Project", *Morocco World News*, 13 January 2024.

construction of green-ammonia terminals, particularly in some of its major southern ports. Without a diversity of hydrogen suppliers or supply routes, Italian hydrogen imports would be highly vulnerable to a single point of failure.

Spain, and by extension Portugal, risks becoming a European green-energy island, as it has focused too closely on attempting to secure the construction of the Barcelona-Marseilles undersea hydrogen pipeline at the expense of seaborne green-ammonia imports and exports. The June 2023 agreement between Spanish energy firm CEPSA and Yara Clean Ammonia to create a maritime transport route for Spanish green ammonia to be shipped from the Port of Algeciras to the Port of Rotterdam helps improve Spain's position. However, it remains unclear whether Madrid has the will and capacity to develop a Western Mediterranean green-ammonia hub in partnership with Morocco and Italy. The position of the EU South, led by Italy and Spain, has suffered from the absence of France as a partner committed to green-energy imports via the Mediterranean. France has embraced the use of green hydrogen and green ammonia in the industrial region of its northern HAROPA (Le Havre-Rouen-Paris) port system and on its Atlantic coast. In this sense, France is part of the greater northern system for MENA-to-Europe green value-chain integration, anchored in Rotterdam and Hamburg.

The future of trans-Mediterranean commercial connectivity as the basis of MENA-to-Europe green value-chain integration is more likely to occur through the nearshoring of the manufacture of finished goods produced with renewable energy. The advancement of electric vehicle (EV) and EV-battery manufacturing in the MENA region offers an opportunity for the major economies of the EU South to create trans-Mediterranean, green-manufacturing corridors. In contrast to its absence from Morocco's green hydrogen ecosystem, Italy already plays a robust role in Morocco's automotive manufacturing ecosystem. Italy has the potential to be a major partner for Morocco in its shift to EV and EV-battery manufacturing, certain components of which will likely be produced using renewable power. Leveraging its Moroccan experience, Italy can reap similar opportunities that are emerging from the nascent EV manufacturing sectors in the UAE and Saudi Arabia. Similar opportunities exist for Spain.

Emerging MENA-to-Europe Hydrogen Highways and Green Value-Chain Integration

Although MENA is currently the world's most prominent oil and natural gas exporting region, it has the potential to become the world's largest renewable-energy-producing region. The Sahara Desert, which covers the majority of North Africa and extends partially into the adjacent Sahel region, receives the world's highest levels of solar radiation and comprises a territory of 9 million square kilometers (sq. km), over twice the EU's total area. If all the solar energy resources of the Sahara Desert were used for power generation, the amount of electricity produced would be 7,000 times greater than the EU's entire electricity demand at any given moment.[4] Similarly high levels of solar radiation are also found in the adjacent Negev desert, Jordanian desert and Arabian Peninsula. These massive solar energy resources are augmented by ample wind power resources, inland, nearshore and offshore.

Even if the MENA region generated electricity from only a minute fraction of its solar resources, it would still produce enough to power the region's climate-friendly economic development and meet a significant proportion of the EU's power demand. The economic and geopolitical logic of establishing MENA-to-Europe renewable-energy supply chains to transport renewable energy from MENA to Europe in a mutually beneficial manner is compelling. While undersea electricity interconnection can play an important role in

[4] W. de Freitas, "Could the Sahara turn Africa into a solar superpower?", *World Economic Forum*, 17 January 2020.

renewable power exports, green hydrogen will be the principal means of transporting renewable energy, given the technologies currently available for commercial-scale renewable-energy storage and transport.

This is why the EU adopted its *Hydrogen Strategy for a Climate-Neutral Europe* in 2020, formalizing the effort to develop low-carbon hydrogen value chains.[5] Germany has been a pioneer in green-hydrogen value-chain development within the MENA region, having committed €9 billion to its green hydrogen strategy.[6] France has also committed €9 billion to developing low-carbon hydrogen value chains,[7] while Italy has made commitments on a similar scale. Spain – which aims to be a supplier to European markets – has committed €18 billion to its hydrogen strategy, doubling its prior anticipated allocation.[8]

Spearheaded by the European Union carbon reduction requirements, global green-transition initiatives are shifting markets towards hydrogen, with some forecasts estimating that the value of the clean hydrogen market will surpass the value of the global LNG trade by 2030, along with the accelerated expansion of trade in green hydrogen.[9] By 2050, the clean hydrogen market will be worth an estimated $1.4 trillion.[10] Conventional natural-gas-derived hydrogen, which is classified as "grey hydrogen", is the result of a process that discharges considerable amounts of carbon dioxide (CO_2) into the atmosphere. Green hydrogen,

[5] European Commission, "A Hydrogen strategy for a climate-neutral Europe", *European Commission*, 8 July 2020.

[6] C. Brooks, "Germany leads pack of countries pouring finance into hydrogen", IHS Markit, 24 March 2022.

[7] L. King, "France: €4 Billion for the Production of Low-Carbon Hydrogen", H2 Today - Professional News on Hydrogen Reported By Hydrogen Specialists.

[8] T. Gualtieri, "Spain May Be Moving Too Fast in Its Green Energy Push", *Bloomberg*, 4 July 2023.

[9] "New Deloitte report: Emerging green hydrogen market set to help reshape global energy map by end of decade, creating US$1.4 trillion market by 2050", Deloitte, 13 June 2023.

[10] M. Tanchum, "Africa's maritime hydrogen highways could enrich the continent and save the world", *The National News*, 13 December 2023; Deloitte (2023).

by contrast, is produced by using electricity generated from renewable sources to split water into its hydrogen and oxygen components, thereby creating a carbon-free (hence, "green") energy carrier. Green hydrogen can be used directly as a fuel or can provide on-demand, climate-smart power by reversing the electrolysis process in a fuel cell, which generates electric current by recombining green hydrogen and oxygen back into water. The "clean hydrogen" market includes green hydrogen and blue hydrogen, the latter of which is formed by applying a carbon capture mechanism to the process of producing natural-gas-derived grey hydrogen. Like liquefied natural gas, blue hydrogen is being touted as a "bridge fuel", for the development of a green hydrogen economy.

Trans-Mediterranean hydrogen pipelines: challenges and opportunities

Italy has focused its efforts on undersea pipelines as the means by which to receive hydrogen imports. Simply extrapolating from its trans-Mediterranean piped natural gas exports, Rome's plans involve no diversification of suppliers, supply routes or offtake mechanisms. Italy has focused on engaging with Germany and Austria to create the "SoutH2 Corridor", which envisages using the undersea natural gas pipeline interconnection between Tunisia and Italy and Italy's gas transmission system to transport hydrogen produced mainly in Algeria to Italy and central Europe. The overland European segments consist of individual projects overseen by the transmission systems operators of each country. Italy's segment constitutes the "Italian backbone" of the corridor and 73% of this backbone will consist of repurposed natural gas pipeline.[11]

The undersea portion of the corridor that interconnects with the Italian transmission system in Sicily has raised questions about the viability of the corridor because the technical and commercial feasibility of trans-Mediterranean pipeline transport

[11] https://www.south2corridor.net/south2

of hydrogen has yet to be adequately addressed.[12] Serious technical and environmental concerns arise when hydrogen is transported through undersea natural gas pipelines as the significantly smaller hydrogen molecules severely degrade the hard steel. Unlike much larger natural gas molecules, hydrogen molecules can permeate the micro-fissures that develop in the pipe due to repeated changes of pressure.[13] While natural gas pipelines typically have a methane emission rate of 3.5%, the emission rate for hydrogen will be significantly higher,[14] with released hydrogen having a global warming potential 7.9 times that of the CO_2 it is intended to replace.[15]

The commercial feasibility of transporting hydrogen through natural gas pipelines is a cause for further doubt due to the added compression costs. Hydrogen is 8.5 times less dense than natural gas and is therefore less energy efficient, requiring 200% more energy to compress than natural gas for the same amount of heat energy content.[16] The compressors in the existing natural gas pipeline network would need to be replaced with units three times as powerful, with three times the suction displacement, and with special capabilities to prevent the smaller hydrogen molecules from leaking.[17] This means the capital expenditures and operating costs of transportation alone, to replace Algeria's natural gas exports to Europe with hydrogen sent via pipeline, would be over three times higher.[18]

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[12] M. Tanchum, "Green hydrogen production in North Africa: Challenges and opportunities", in K. Young and K. Wolff (eds.), *Energy Transitions in the Middle East – Opportunities and Challenges*, Bloomsbury.

[13] M. Barnard, "Paul Martin Talks H2 Science Coalition & More Problems with Hydrogen", *Clean Technica*, 1 March 2022.

[14] J. Burgess, "Blue hydrogen 20% worse for GHG emissions than natural gas in heating: study", *S&P Global*, 12 August 2021.

[15] N. Warwick, P. Griffiths, J. Keeble, A. Archibald, J. Pyle, and K. Shine. "Atmospheric implications of increased Hydrogen use", *Government of the United Kingdom*. April 2022.

[16] P. Martin, "Is Hydrogen the Best Option to Replace Natural Gas in the Home? Looking at the Numbers", *Clean Technica*, 14 December 2020.

[17] Ibid.

[18] Ibid.

The hydrogen initially intended to be shipped via this network is not even green hydrogen produced from renewable energy, but blue hydrogen. Algiers aims to capture 10% of the European hydrogen market by exporting blue hydrogen, and sees the development of green hydrogen as a long-term goal.[19] Considering that Algeria would need a 2,900% increase in renewable-power generation capacity over its current level to meet its own 2030 renewable energy target, the prospects for Algerian green hydrogen seem long-term indeed.[20] In March 2023, Algeria unveiled its first hydrogen roadmap. Although formulated in cooperation with the German development agency GIZ,[21] the 30-year framework contains no specific target commitments for developing green hydrogen. Four months earlier, in December 2022, Algeria signed a declaration of intent with Germany's VNG, a subsidiary of German utility EnBW, to develop a pilot green-hydrogen plant. Although Germany's KfW agreed to finance the 50MW pilot green-hydrogen facility,[22] the agreement appears to have been a precursor to clearing a path for German purchases of Algerian natural gas. In early February 2024, VNG – formerly a major purchaser of Russian natural gas for German businesses – signed a landmark deal with Sonatrach to become the first German company to buy Algerian pipeline gas.[23]

Even if green hydrogen were available for export from Algeria or Tunisia, whose own pilot project is still in its initial stages

[19] Embassy of Algeria to Croatia, "Hydrogen Production: Algeria in a Position to Play Leading Regional Role".

[20] Ministère de l'Énergie et des Mines, "Energies Nouvelles, Renouvelables et Maitrise de l'Energie"; M. Nachmany et al., "Climate Change Legislation in Algeria: An Excerpt from the 2015 Global Climate Legislation Study", A Review of Climate Change Legislation in 99 Countries.

[21] "Feuille de route de développement de l'hydrogène: fournir au marché européen 10% de ses besoins à l'horizon 2040", Algérie Presse Service, 23 March 2023.

[22] "Germany to back 50 MW green hydrogen project in Algeria", *Renewables Now*, 25 October 2023.

[23] S. Elliott and J Burgess, "Germany's VNG to begin Algerian gas imports under mid-term deal with Sonatrach", *S&P Global*, 2 September 2024.

of development, the above-mentioned technical, commercial and environmental problems would remain. The concept of the SoutH2 Corridor builds on a 2021 study of the potential of Tunisia's hydrogen industry, published by GIZ. This study, however, did not address the previously discussed challenges involved in transmitting hydrogen through undersea natural gas pipelines.[24] The proposal to transport a blend of 20% hydrogen and 80% natural gas does not adequately address the issues. Even if green hydrogen were used, the 80-20 blend would not even be "20% green". The 80-20 proportion is by volume and contains only 86% of the energy content of the same amount of natural gas alone. The 80-20 blend requires 14% more of the blend to produce the same amount of energy as natural gas, making the greenhouse gas reduction of a blend with 20% green hydrogen less than 6% when accounting for the 13% more energy required to compress the 80-20 blend.[25]

Similar considerations are at play for the proposed Barcelona to Marseille (BarMar) undersea hydrogen pipeline announced in late 2022, with an extension to Germany announced in early 2023.[26] Slated to be operational by 2030, with an annual capacity of 2 million tons, the BarMar pipeline could theoretically also serve as a conduit for North-African-produced green hydrogen, making Spain an international hydrogen hub along with Italy. For France, the entry of hydrogen via the Mediterranean is not a priority. Paris has centred its green hydrogen efforts on the Seine-Maritime axis in Normandy, with domestic production and the receipt of imports at the HAROPA port system, France's leading port.[27] Additionally, a 40-hectare green-hydrogen production complex is being constructed on France's Atlantic

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[24] Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH, "Study on the Opportunities of "Power-to-X in Tunisia", GIZ, 2021.

[25] P. Martin (2020).

[26] "H2Med: le pipeline d'hydrogène entre Barcelone et Marseille sera étendu à l'Allemagne", *La Tribune*, 23 January 2023.

[27] "Vers un couloir d'hydrogène renouvelable entre les Emirats et Le Havre", *France Hydrogène,* 31 January 2024.

coast on the Ambès peninsula in Gironde, in the area of the Grand Port Maritime de Bordeaux.[28] Both locations are focused on the transport of green hydrogen in the form of its derivative, green ammonia.

While it may turn out that the technical and commercial obstacles to undersea pipeline hydrogen exports can be overcome, both Italy and Spain have paid inadequate attention to preparing themselves to receive seaborne shipments of green ammonia, thus allowing Europe's non-Mediterranean ports, such as Rotterdam and Hamburg, to develop a significant first-mover advantage (see next section). Following in the footsteps of Rotterdam and Hamburg, the Deputy Director of the HAROPA PORT held preliminary discussions in Dubai, in December 2023,for Le Havre to receive seaborne shipments of ammonia produced in the UAE.[29]

Green ammonia: emerging gatekeeper for MENA-to-Europe green value-chain integration

Green ammonia is currently the most cost-effective way to store and transport green hydrogen and will become the dominant form of traded green hydrogen, assuming no major disruptive technological changes take place in the renewable energy sector. In the form of green ammonia, green hydrogen can be easily transported by ship and is therefore a versatile energy carrier for renewable energy, expanding the scope of opportunities for developing a diverse array of renewable-energy-based production value chains. A nitrogen-hydrogen compound, ammonia constitutes the basic component of most synthetic fertilisers upon which modern agri-food production depends. While the nitrogen is sourced from the air, the hydrogen used for ammonia production is primarily grey hydrogen made from

[28] "Gironde: projet de construction de l'usine de GH2 à Ambès", *L'Usine Nouvelle*, Press Release, 31 August 2023.

[29] "Vers un couloir d'hydrogène renouvelable entre les Emirats et Le Havre", *France Hydrogène*, 31 January 2024.

natural gas, which accounts for at least 80% of the variable cost of the fertilizer.[30] Producing synthetic fertilizer from green ammonia would not only reduce the carbon footprint of agri-food production, it would make fertiliser more resilient by being less vulnerable to natural-gas price spikes and supply disruptions. Since fertiliser production currently accounts for about 70% of global ammonia consumption, there is already offtake demand for green ammonia, making it easier to obtain financing for the construction of green ammonia production and transportation infrastructure.[31]

The Netherlands is the world's second-largest food exporter and a large consumer of synthetic fertilizer. Using 2019 as a baseline year for comparison, the Netherlands used an extraordinary 273.8 kilograms of fertilizer per hectare of arable land, well above the already high Western European norm, ranging from Italy's 128 kg to Germany's 174.1 kg per hectare.[32] Because of its high reliance on fertilizer, the Netherlands has been at the forefront of sustainable fertilizer production, pioneering production and offtake arrangements with the MENA region. The world's largest export-focused fertilizer platform, Fertiglobe, is jointly owned by the Netherlands' fertilizer producer OCI NV and the Emirates' Abu Dhabi National Oil Company (ADNOC). In November 2023, Fertiglobe produced Egypt's first consignment of certified green ammonia, at facilities of its subsidiary, Egypt Basic Industries Corporation, located near the Red Sea port of Ain Sokhna.[33]

In March 2022, the Netherlands signed a memorandum of understanding (MoU) with the UAE to collaborate in the

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[30] R. Sterk, "High fertilizer prices, tight supplies may adversely affect 2022 acreage", *FoodBusinesNews*, 12 December 2021.

[31] International Energy Agency (IEA), *Ammonia Technology Roadmap*, October 2021.

[32] "Fertilizer consumption (kilograms per hectare of arable land) – Spain, France, Italy, Netherlands, Germany", *World Bank*, 2024.

[33] "Fertiglobe exports world's first certified green ammonia from Egypt", *Ahramonline*, 20 November 2023.

creation of a clean-hydrogen export-import corridor from the UAE to the Netherlands, as a gateway to the rest of Europe. Concurrently in March 2022, the German energy firm RWE unveiled its plans to construct a green-ammonia import terminal in Brunsbüttel, near Hamburg, to be operational in 2026, with annual capacity to receive 300,000 tons.[34] The plans to create the Brunsbüttel green-ammonia terminal came on the heels a series of 2021 clean hydrogen agreements ADNOC had signed with German industrial manufacturers, including metals processor Aurubis (see below), for proof-of-concept supply agreements. Concurrently, ADNOC and the UAE's AD Ports signed an MoU with Hamburg-based port logistics firm HHLA to collaborate on realizing the Port of Hamburg's ambition to become a hydrogen import hub.[35]

The UAE's 2030 green-hydrogen production target is 1 million tons of green hydrogen and derivatives from its various operations across the MENA region, such as Fertiglobe's green-ammonia production facilities in Egypt.[36] The UAE's annual green-hydrogen demand is forecast to be 200,000 tons.[37] The remaining 300,000 tons produced locally and the 500,000 tons produced outside the UAE will be exported internationally.[38]

Both Rotterdam and Hamburg also have their eyes on green ammonia exports from Saudi Arabia, which is constructing a massive $8.4 billion dollar green-hydrogen facility, slated to be operational in 2026, with an initial production capacity of 1.2 million tons of green ammonia per year.[39] In 2023, Saudi

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[34] N. Hakirevic Prevljak, "Germany: RWE to build green ammonia import terminal in Brunsbüttel", *OffshoreEnergy*, 18 March 2022.

[35] "ADNOC Expands Strategic Partnerships Across the Hydrogen Value Chain with Leading German Companies", ADNOC, 21 March 2022.

[36] "Masdar accelerates green hydrogen ambitions after joining forces with UAE energy champions", *Masdar*, 9 January 2023.

[37] Ibid.

[38] Ibid.

[39] N. Al-Nasr et al., "Neom Green Hydrogen Company Completes Financial Close At A Total Investment Value Of Usd 8.4 Billion In The World's Largest Carbon-Free Green Hydrogen Plant", *Neom*, 22 May 2023.

Arabia signed an engineering, procurement and construction agreement with Air Products (the US-headquartered industrial chemicals and gases giant with significant subsidiaries across Europe, Asia and the Middle East). Riyadh also signed a 30-year offtake agreement for all the green ammonia produced at the plant, which will make Saudi Arabia a player in global green-hydrogen value chains.[40]

While Saudi Arabia and the Netherlands signed a 2023 MoU, with Saudi officials acknowledging Rotterdam as one of the primary destinations for green ammonia distribution in Europe,[41] Rotterdam was making up ground on Hamburg. Air Products has already earmarked a significant portion of the offtake for Germany as part of its November 2022 agreement with Mabanaft to build Germany's first large-scale green ammonia terminal in the Port of Hamburg, expanding Mabanaft's existing tank terminal and using Air Products' Hamburg facilities to reconvert green ammonia to green hydrogen for distribution to buyers across northern Germany.[42]

The Netherlands is also playing a prominent role in Morocco's green-ammonia ecosystem, which is one of the leading green-ammonia ecosystems in the region. While Germany's GIZ originally helped the initiation of Morocco's green hydrogen sector through two pilot projects conducted within the framework of development aid, private green-hydrogen firms from other European countries have taken the lead. Morocco's largest green-ammonia project under construction is the Ireland-headquartered Fusion Fuel's HEVO facility, which is slated to have an initial annual capacity of 183,000 tons by 2026.[43] Rabat signed an MoU with Dutch oil-trading giant

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[40] Ibid.

[41] "Saudi Arabia and Netherlands sign MoU to collaborate on green energy", *Arab News*, 11 May 2023.

[42] "Air Products and Mabanaft Plan to Build Large-Scale Green Energy Import Terminal in Hamburg", *Mabanaft*, 17 November 2022.

[43] M. Tanchum, "Morocco's New Challenges as a Gatekeeper of the World's Food Supply: The Geopolitics, Economics, and Sustainability of OCP's Global

Vitol to market green ammonia in Europe.[44] On 25 August 2022, Netherlands-based green ammonia company Proton Ventures secured financing from a Dutch investment firm to build a green ammonia plant in the port of Jorf Lasfar.[45] The investment was backed by a loan guarantee from the Dutch credit export agency Atradius DSB.

Within the same time-frame as Proton Ventures' investment in Moroccan green-ammonia production, Dutch state-owned natural-gas transmission network operator Gasunie, the Netherlands-headquartered bulk handling giant HES International, and the Netherlands' global leader in tank storage Vopak formed a consortium for the construction of a new green-ammonia import terminal in Rotterdam's Maasvlakte port, which is expected to be operational by 2026.[46] Cementing the efforts to create a corridor for Moroccan green ammonia to reach Rotterdam, the Netherlands and Morocco established a joint $300 million infrastructure investment fund in 2023.[47] On completion of the projects currently under development, Morocco could export over 1-3 million tons of green hydrogen or its green ammonia equivalent to Europe annually.[48]

In January 2024, the Italian government allocated funds for a feasibility study to be conducted on facilitating the transport of green ammonia from Morocco to Italy's Port of Trieste, with the possibility of transshipment to central and eastern Europe, utilizing the already established cross-border

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Fertilizer Exports", Middle East Institute, 18 January 2022.

[44] "Morocco outlines plans for new green ammonia project", argus, 20 July 2021.

[45] Y. Benabdellah, "Le projet pilote de production d'ammoniac vert ouvre de grandes perspectives pour le Maroc", *Medias24*, 4 September 2022.

[46] M. Tanchum, "Can Singapore unlock Africa's green hydrogen potential?", Centre for African Studies, Nanyang Technological University, 15 September 2023.

[47] S. Zouiten, "Morocco, Netherlands Launch €300 Million Investment Fund for Green Initiatives", *Morocco World News*, 22 June 2023; "Morocco, The Netherlands strengthening renewables cooperation", *Enterprise*, 22 June 2023.

[48] M. Tanchum, "Africa's maritime hydrogen highways could enrich the continent and save the world"…, cit.

hydrogen collaboration that Italy's Friuli-Venezia Giulia region enjoys with Croatia and Slovenia.[49] Italy's comparatively late engagement in an offtake relationship with Morocco's green hydrogen ecosystem seems to reflect the larger issue of the influence of Rome's North African oil and natural-gas relations inhibiting its development of energy diplomacy based on its renewable energy interests. Despite Morocco's ranking as the most attractive renewable energy market for investment, according to the Renewable Energy Country Attractiveness Index (RECAI) published by international accounting firm EY (Ernst & Young),[50] Italy has virtually no presence in Morocco's solar power sector. Enel Green Power (EGP), the renewable-energy subsidiary of Italy's multinational power giant Enel, does operate two wind power plants in Morocco and is constructing a third that will bring EGP's total wind power capacity in Morocco to 807.8 MW.[51] In 2021, the Italian multinational oil and natural-gas services company Saipem and Italy-based Alboran Hydrogen signed an MoU that included their joint construction of a green-ammonia production plant in Morocco,[52] but apparently has remained moribund, leaving Italy entirely absent from Morocco's green hydrogen ecosystem.

Morocco will likely emerge as a green-ammonia export hub that could also include output from Mauritania, its direct neighbour to the south, and Namibia, further down the Atlantic African coast. Total Eren, French energy giant TotalEnergies' renewable subsidiary, which is building a $10 billion project to establish green ammonia production in Morocco's Guelmim-Oued

[49] A. Dokso, "Green Corridor Project Connects Italy and Morocco", *H2 Energy News*, 15 January 2024.

[50] The normalised score is obtained by taking the RECAI "raw" score and dividing it by the log of GDP. "Renewable Country Energy Attractive Index (RECAI), 60th edition", *EY*, November 2022, p. 20.

[51] "Morocco – We are helping Morocco manage the country's energy transition process", *Enel Green Power*, 30 September 2022.

[52] M. Kouamé, "Production d'hydrogène vert Saipem et Alboran Hydrogen s'activent", *Les Ecos*, 15 March 2021.

Nour region,[53] is also jointly developing a green-ammonia production complex in Mauritania's Nouadhibou coastal region with Britain's Chariot. The initiator of the Nouadhibou project, Chariot already signed a 2022 MoU with the Port of Rotterdam to offtake up to 600,000 tons of green hydrogen annually.[54] In June 2023, the Port of Rotterdam and Gasunie signed an MoU to develop the necessary infrastructure to create a green-ammonia supply chain from Namibia to Rotterdam.[55] Germany is also active in Atlantic African green-ammonia production, with German firm Conjuncta building a production complex near the Mauritanian capital of Nouakchott. A joint venture in partnership with Fertiglobe and the Emirati-Egyptian firm Infinity power, the $34 billion Noakchott facility will have an annual production capacity of 8 million tons of green hydrogen or derivative equivalent.[56] Germany is also playing a prominent role in the development of Namibia's green-ammonia production infrastructure.

Green ammonia fueling European green manufacturing

The impressive green-hydrogen economic diplomacy conducted respectively by the Netherlands and Germany towards the MENA region forms a synergy that favours the EU's northern and Atlantic shores over the Mediterranean, as no comparable level of engagement has been demonstrated by Italian and Spanish firms. The lacuna is particularly striking for Italy, given the Italian peninsula's central geographic location in the

[53] J. Rahhou, "Total Eren to Launch Green Hydrogen Megaproject in Morocco", *Morocco World News*, 4 February 2022; *The Status of Wind in Africa*, GWEC Africa WindPower, October 2023.

[54] M. Tanchum, "Can Singapore unlock Africa's green hydrogen potential?"…, cit.

[55] "Namibia and the Netherlands work together in the field of green hydrogen", Port of Rotterdam, 21 June 2023.

[56] M. Tanchum, "Africa's maritime hydrogen highways could enrich the continent and save the world"…, cit.

Mediterranean basin and the fact that Italy is the second largest manufacturer in Europe. As per the previously mentioned agreements between ADNOC and German manufacturers, Germany received its first consignment of Emirati-made blue ammonia in 2022, produced by Fertiglobe in the Ruwais industrial complex in Abu Dhabi.[57] Although produced by the Dutch-Emirati fertilizer manufacturer, the blue ammonia exported to Hamburg was used for industrial manufacturing, with the demonstration cargo being delivered to Aurubis, a European leader in the production of non-ferrous metals.[58] Aurubis used the Emirati blue ammonia in its copper wire rod plant as a proof-of-concept to pave the way for the eventual use of green ammonia in the energy-intensive manufacturing processes used in multi-metal production.[59]

In addition to copper processing, Europe is looking to imported green ammonia as a feedstock fuel in steel production to make "green steel". The worldwide steel sector accounts for about 7% of global CO_2 emissions.[60] In 2023, Europe's first green-steel production plant, the H2 Green Steel plant, began operation in Sweden with commercial sales expected in 2025.[61] The H2 Green Steel plant will soon be followed by the EU-funded HYBRIT (Hydrogen Breakthrough Ironmaking Technology) green steel manufacturing facility in Sweden, scheduled to be operational in 2026.[62] Beyond Sweden, major green steel production projects are underway across Europe – including in Spain, France and Germany.[63] While Italy's largest

[57] "ADNOC Sends First Low-Carbon Ammonia Shipment from the UAE to Germany", ADNOC, 1 September 2022.

[58] Use Aurubis website for description www.aurubis.com

[59] Ibid.

[60] European Commission, JRC Publications Repository, J. Somers, Technologies to decarbonise the EU steel industry, 2022.

[61] F. Jones, "Europe's first commercial green steel plant to open in Sweden", Mining Technology, 22 February 2022.

[62] European Commission, Climate Action, "The HYBRIT story: unlocking the secret of green steel production", 20 June 2023.

[63] M. Savage, "The race across Europe to build green steel plants", *BBC News*,

steel plant is centrally located in the southern deep-sea port of Taranto, with plans for some operations to be fueled by green hydrogen,[64] the port's capacity to act as a green-ammonia receiving terminal has not been developed. Instead of having a diversity of suppliers through seaborne green ammonia, the greening of Italy's steel industry will either rely entirely on the development of sufficient quantities of locally produced green hydrogen. Unless Taranto or Italy's other southern ports develop Mediterranean green-ammonia terminals like those in Rotterdam or Hamburg, Europe's green value-chain integration with the MENA region will bypass most of Europe's Mediterranean shores.

MENA-to-EUROPE Green-Manufacturing Value Chains: EV Manufacturing as an indicator

Aside from green hydrogen as a feedstock or fuel for manufacturing, the integration of MENA-to-Europe green value chains will also be achieved through the export to Europe of intermediate products and, especially, finished goods produced in the MENA region using renewable energy. While green fertilisers produced in Morocco and other parts of the MENA region are likely to service European agri-food production, the main green intermediate input for European industrial manufacturing will likely be green metals. The trend was initiated in 2021 by the UAE, the world's fifth-largest aluminum producer, when Emirates Global Aluminum (EGA) began the world's first green aluminum production using local solar power. EGA's trademark CelestiAL solar aluminum was sold to German automaker BMW. In 2022, EGA signed an agreement with Austrian-headquarter Hammerer Aluminum Industries to supply CelestiAL solar aluminum from which

17 February 2023.

[64] "Europe offers $400 mn for Italian green H2 valley that will decarbonize steel", *Emerging Technology News (ETN)*, 27 February 2024.

Hammerer will manufacture components for German car manufacturing operations. Saudi Arabia's rising mining and metals processing giant Ma'aden seeks to emulate EGA's success in aluminum, as well as developing market share for low-carbon copper and steel.[65] Morocco has similarly developed its metals processing industry, with a particular focus on EV battery metals.

Morocco is the leading automotive manufacturer in the MENA region, with annual production capacity expected to exceed 1 million vehicles by 2025.[66] The manufacturing plants of European automakers Groupe Renault and Groupe PSA (now part of the Stellantis conglomerate) form the anchor of Morocco's automotive ecosystem, which is now supported by about 250 international firms from the US, Europe, Japan, China and elsewhere, operating their own local manufacturing plants to supply automotive components. While Spanish firms participate in Morocco's automotive sector, Italian automotive companies constitute about 10% of the firms operating in Morocco's automotive ecosystem.[67] The European market accounts for 90% of Morocco's exports,[68] with Europe's two best-selling car models – the Peugeot 208 and Renault's Dacia Sandero – made in Morocco.[69] With Morocco eyeing the production of 250,000 electric cars per year,[70] the manufacture

[65] "Al-Mudaifer: Saudi Arabia Keen to Become International Hub for Green Minerals Processing", Saudi Press Agency, 10 October 2023.

[66] M. Tanchum, "Morocco's green mobility revolution: The geo-economic factors driving its rise as an electric vehicle manufacturing hub", Middle East Institute, 26 August 2022.

[67] M. Tanchum, "The Food-Energy Nexus and Italy–Morocco Cooperation", Istituto Affari Internazionali (IAI), 3 March 2023.

[68] "Voici à quoi pourrai ressembler la première gigafactory de batteries au Maroc", in Dossier "Entretien avec Ryad Mezzour: Indistrie, export.. un premier bilan", *Medias24*, 12 August 2022.

[69] J. Warrick, "Best-selling cars in Europe. The Tesla Model Y finished 2023 as the year's best selling car", Autocar, 15 February 2024.

[70] M. Tanchum, "Morocco's green mobility revolution: The geo-economic factors driving its rise as an electric vehicle manufacturing hub"…, cit.

of the EV versions of the Peugeot 208 and the Dacia Sandero on Moroccan soil is a near-term likelihood.[71] Germany's Opel and Italy's Fiat have already begun the production of EV models in Morocco.[72] The robust role that Italian firms play in Morocco's automotive ecosystem, and to a lesser extents Spanish firms, provides these EU south countries with an opportunity to play a key role in green value-chain integration as Morocco develops its green mobility sector and starts to power automotive production with renewable energy.

The use of renewable energy in any aspect of production would reduce the carbon footprint of Moroccan EV exports to Europe. Morocco's rise as an EV manufacturing giant depends on the local manufacture of lithium-ion batteries, which represent 30% to 40% of the cost of the average EV.[73] Morocco's massive phosphate reserves, which form the backbone of its fertilizer industry, come into play as the EV industry is shifting away from lithium batteries using nickel, manganese and cobalt, in favor of lithium iron phosphate (LFP) batteries.[74] By manufacturing LFP batteries, Morocco would enjoy a cost advantage of upward of 70% per kilogram.[75]

Morocco is constructing dedicated solar power plants to shift its phosphate mining and fertilizer production operations to using renewable energy. The expansion of phosphate and phosphoric acid production to make LFP EV batteries would require Morocco's additional output of phosphates and phosphoric acid to be powered by renewable energy sources. Morocco's renewable power also provides another competitive

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[71] Ibid.

[72] M. Tanchum, "Why North Africa is a natural choice for Brics expansion", *The National News*, 25 August 2023.

[73] M. Tanchum, "Morocco's green mobility revolution: The geo-economic factors driving its rise as an electric vehicle manufacturing hub"…, cit.

[74] For example, Tesla announced in its Q3 2021 report, "For standard range vehicles, we are shifting to Lithium Iron Phosphate (LFP) battery chemistry globally".

[75] "Lithium Iron Phosphate on the QuantumScape Solid-State Lithium-Metal Platform", QuantumScape, 7 September 2021.

advantage, as it helps automakers meet their own targets for reducing the carbon footprint of their operation. Renault, for example, has set carbon-reduction goals for its EV batteries of 20% by 2025 and 35% by 2030, compared to 2020 levels.[76]

Following Morocco's example of developing a green energy ecosystem though green mobility, the UAE and Saudi Arabia have recently started their own fledgling EV production, thus opening up first-mover opportunities for Italian and Spanish players to enter these embryonic green mobility ecosystems.

In October 2022, the UAE's M Glory holding company opened the Al Damani Electric Vehicle Factory, the country's first electric car manufacturing plant, with an initial production capacity of 10,000 EVs per year.[77] With plans for capacity expansion, the Al Damani plant is looking to produce 55,000 EVs annually.[78] The UAE hopes to boost its EV manufacturing by leveraging its production of green aluminum. Electric vehicles are currently composed of 25-27% more aluminum than their internal-combustion-engine counterparts,[79] and this is likely to greatly increase as manufacturers seek to reduce EV weight and production times.[80] Domestically produced green aluminum, such as CelestiAL solar aluminum, could provide a significant advantage for the further development of EV manufacturing in the UAE. The use of CelestiAL solar aluminum would mean that a significant part of EV manufacturing would be powered by renewable energy sources, even in the early stages of the sector's development.

In September 2023, EV maker Lucid Group, majority-owned by Saudi Arabia's sovereign wealth fund, opened its first Saudi

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[76] "Voiture électrique: Renault sécurise ses approvisionnements de cobalt au Maroc", *La Tribune*, 2 June 2022.

[77] I. Oxborrow, "M Glory's electric vehicle manufacturing plant opens in Dubai", *The National News*, 5 October 2022.

[78] Ibid.

[79] "Electric Vehicles to Transform Aluminium Demand", CRU Group, *Mining Technology*.

[80] "The use of aluminium in the ev market", *Metal Warehouse*, 17 August 2022.

factory at the Red Sea port of Jeddah.[81] With initial capacity to assemble 5,000 vehicles per year from semi-knocked-down kits manufactured by the company in the United States, Lucid plans to transition its Jeddah plant to completely-built-unit production, to manufacture a total of 155,000 EVs annually.[82] One year earlier, Riyadh began the development of steel and EV battery metals manufacturing plants to supply the development of a domestic EV manufacturing sector.[83] While possessing smaller phosphate reserves than Morocco, Saudi Arabia is also seeking to leverage Ma'aden's phosphate operations for the manufacture of LFP batteries. EV manufacturing in Saudi Arabia, with both component manufacturing and assembly powered by renewable energy, would provide opportunities for MENA-to-Europe green value-chain integration.

Conclusion

Keeping the European Union green and prosperous requires greater MENA-to-Europe green value-chain integration. The growing trend of nearshoring production to the MENA region, combined with the imminent emergence of MENA as one of the world's largest renewable-energy producing regions is accelerating the process. While the Mediterranean ports of EU Member States could play a vital role in the pattern of commercial connectivity that undergirds MENA-to-Europe green value-chain integration, trans-Mediterranean commercial connectivity is not geographically pre-ordained to play a dominant role. The initial phase of the process of MENA-to-Europe value-chain integration has seen Europe's northern

[81] "Lucid opens first international EV factory in Saudi Arabia", *Reuters*, 27 September 2023.

[82] "Lucid Group Makes History in Saudi Arabia as it Opens Country's First-Ever Car Manufacturing Facility", *LUCID*, 27 September 2023.

[83] "Saudi Arabia announces $6 billion investments in steel complex, EV metals plant", *Reuters*, 6 May 2022.

ports surpass Europe's Mediterranean ports, as Rotterdam and Hamburg have actively engaged with MENA nations to become the main receiving terminals for renewable energy exports in the form of seaborne green ammonia.

With the ports of the Italian peninsula strategically located in the geographic heart of the Mediterranean basin and Italy being the EU's second largest manufacturer, the lack of comprehensive action to promote the receipt of MENA-produced green ammonia as feedstock and fuel for industrial manufacturing constitutes a strategic lacuna in Rome's energy diplomacy. While it is natural for Italy's policy orientation to be shaped by past oil and natural gas relationships, Rome needs to actively engage with the new opportunities provided by renewable energy to diversify supply sources and supply routes. This need to rebalance was reflected in Rome's January 2024 decision to fund a feasibility study on facilitating the transport of Moroccan green ammonia to the Port of Trieste. The initiative is a step in the right direction and should be accelerated as well as expanded to Taranto and Italy's other major southern ports.

The Netherlands and Germany have been at the forefront of the development of green-ammonia production in the MENA region and sub-Saharan Africa, making Rotterdam and Hamburg the leading ports for MENA-produced green ammonia. The green-hydrogen economic diplomacy conducted respectively by the Netherlands and Germany towards the MENA region forms a synergy that favors the EU's northern and Atlantic shores over the Mediterranean. The governments of Italy and Spain should facilitate cooperation between Italian and Spanish firms, transmission systems operators and port operators to achieve a comparable level of engagement with the MENA region. Italy and Spain should also cooperate with Greece to leverage the latter's engagement with Egypt, the UAE and Saudi Arabia for a comprehensive EU Mediterranean strategy.

The nearshoring of industrial manufacturing to the MENA offers Italy and Spain an excellent opportunity for MENA-to-Europe green value-chain integrations, as intermediate products and finished good are increasingly produced using renewable energy. Italian firms and, to a lesser extent, Spanish firms form key pillars of Morocco's automotive manufacturing ecosystem. As Morocco sets its sights on producing 250,000 EVs per year, with at least some of the production using renewable energy, Italy and Spain are well positioned to advance green value-chain integration. The fact that the UAE and Saudi Arabia have launched embryonic EV manufacturing sectors gives Italy and Spain another major opportunity to achieve MENA-to-Europe green value-chain integration. Because EV manufacturing is playing a leading role in the development of green-energy manufacturing ecosystems in MENA nations, the involvement of firms from southern EU Member States will serve as barometer for their wider future involvement.

The loss of position to the northern EU ports should serve as a cautionary tale for Italy, Spain and Greece. Offtake of MENA-produced green energy will occur if it serves southern European agri-food production and industrial manufacturing. As production continues to shift to the Mediterranean southern shores and the Middle East, trans-Mediterranean corridors will emerge from MENA-to-Europe green value-chain integration only where southern EU Member States invest in climate-smart, sustainable factories and farms in the MENA region powered by renewable energy. While sufficient transportation and storage infrastructure, along with digital platforms, are perquisites, Mediterranean EU Member State-MENA connectivity depends on southern European private-sector investment in production in the MENA region and proactive government action to promote it.

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