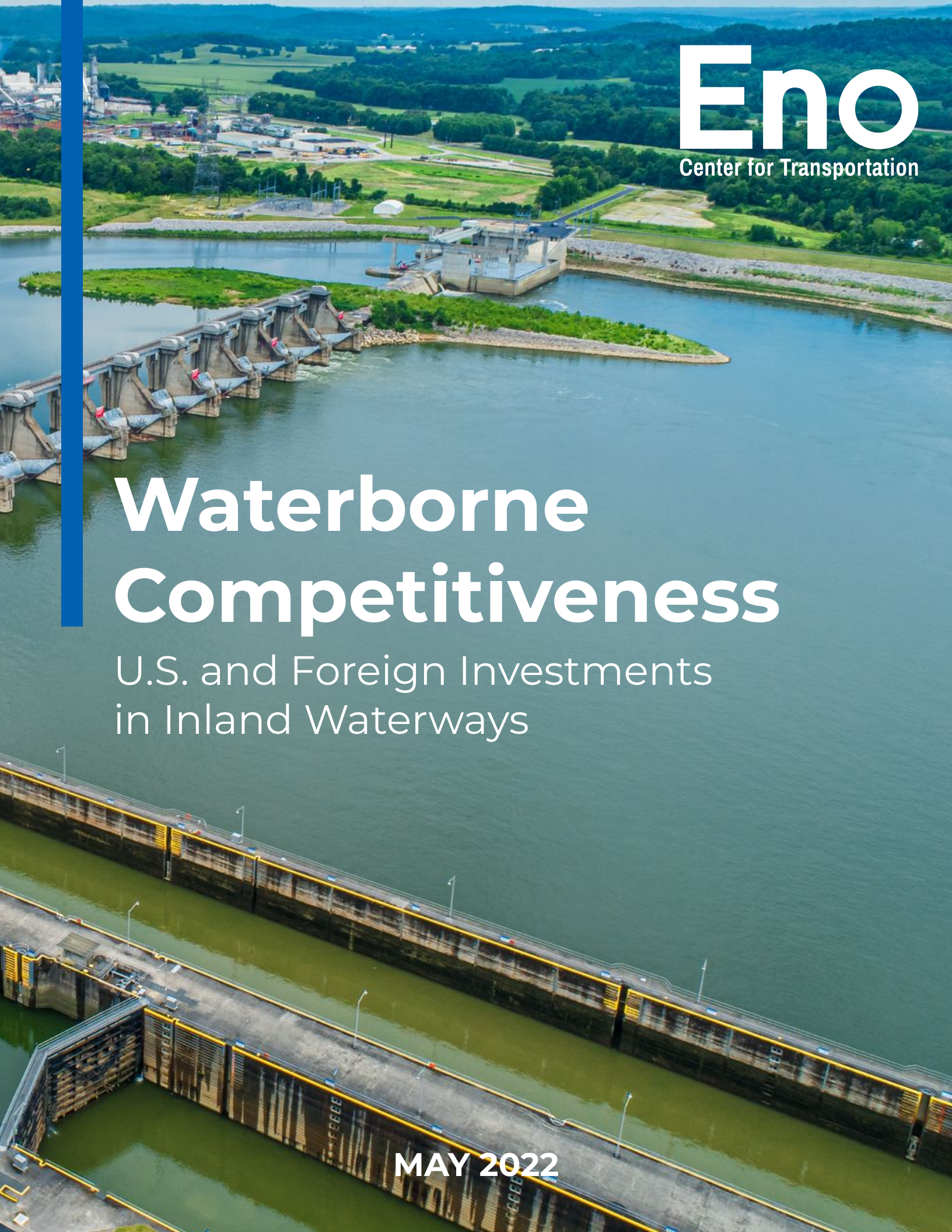

Eno
Center for Transportation

Waterborne Competitiveness

U.S. and Foreign Investments in Inland Waterways

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The Center for International Trade and Transportation (CITT) is based in California State University, Long Beach's College of Professional and Continuing Education (CPaCE). CITT is dedicated to delivering innovative workforce-centric research in the goods movement industry and applying it to curriculum development, training, and professional development programs across the educational spectrum.

About the Eno Center for Transportation

The Eno Center for Transportation is an independent, nonpartisan think tank whose vision is for a transportation system that fosters economic vitality, advances social equity, and improves the quality of life for all. The mission of Eno is to shape public debate on critical multimodal transportation issues and build a network of innovative transportation professionals.

Table of Contents

Executive Summary

The inland waterways network in the United States is a vital trade corridor serving energy, agriculture, and other freight shipments internally and for export. Major global events like the war in Ukraine and the resulting supply chain disruptions illustrate the importance of the system and create an urgent need for efficient movement of goods. While infrastructure investments in recent years have significantly improved the system, this report shows how competition from other global waterways could limit this success if quality maintenance and operations are not continued.

Several rivers and canals make up the 12,000-mile U.S. inland waterway network. These include the infrastructure that enables commercial navigation on the Mississippi River, the Ohio River, the Gulf Coast Intracoastal Waterway, and others. The network moves over 500 million tons of freight annually, constituting mostly bulk goods, and is a low-cost route for exporters. Inland waterway systems frequently carry goods that are too large for trucks or rail cars, such as windmill blades, booster rockets, and oversize machinery. The inland waterways are also strategically important for the military, moving vehicles and components for shipbuilding.

However there are two main threats to these strategic trade and military advantages. First, underinvestment in the system's infrastructure, maintenance, and operations has degraded the service levels on the rivers, making it less reliable and less competitive. Investments from the federal government over the past decade have made substantial progress in increasing reliability and clearing the maintenance backlog; but continued prioritization of projects that support efficient operations will be necessary to increase shipper confidence.

The second threat is external. While the United States has been upgrading domestic inland waterway infrastructure, other countries have been doing the same for their own military and commercial advantage. Investments in economic development and infrastructure have boosted traffic on rivers like the Amazon and Yangtze. Some of this investment comes from state-owned enterprises in countries like China, which could put American exporters at a competitive disadvantage.

To inform discussions about investments and the future of the U.S. inland waterway network, this research examines six cases of major freight rivers around the world, evaluating their governance, freight flows, investment levels, and role in the global supply chain.

In South America, the Amazon River is naturally navigable and although comparably little freight is moved on the river, freight volumes are growing rapidly as Brazil

develops its agriculture economy. Domestic and foreign companies are investing in port facilities to leverage the river's use as an export corridor. The Paraná and Paraguay river system provides access for shippers in Brazil, Paraguay, Bolivia, and Argentina. Unlike the Amazon, it already traverses through urban areas and farming areas, but waterway governance and management lack coordination between the countries. Relatively small investments could greatly increase its utility and use, but there are no current initiatives to make this happen.

The Rhine and Danube rivers in Europe are both heavily used for internal and export freight. Along with the member states, the European Union boosted investment in infrastructure and operations; and has strategically planned the Rhine to accommodate significant container-on-barge shipments. Moving high value goods requires high system reliability and coordination with landside infrastructure, and helps alleviate demand on congested parallel roadways and railways.

In Southeast Asia, China developed the Yangtze River into the world's busiest freight waterway, connecting industrial and farming hubs in the country's interior to the seaports in Shanghai. While the Chinese government manages investments on the waterways, local jurisdictions invest in port infrastructure, in some cases leading to overdevelopment. As the central government improves connections between these facilities and land-based modes of transportation, the river could see even more growth in traffic. The Mekong River has significant investments in hydroelectric dams, but relatively few investments in navigation. While the Mekong is used for exports in Cambodia and Vietnam, most dams are not navigable and, in some cases, threaten navigation by disrupting natural water flow.

These examples provide important lessons for policymakers and shippers in the United States. The United States benefits from having the inland waterways system contained within its borders and governance centralized with the federal government. The United States should use the advantage to build on the momentum of recent developments and investments to create more strategic, multimodal freight planning with inland waterways as a key part of that strategy. That investment, coupled with improved operational practices and a sound asset management plan, will be a significant boon to existing users and attract new shippers.

At the same time. the United States needs to carefully watch the development of other nations' freight waterway corridors with an eye toward economic competitiveness and national security. While freight traffic is relatively low on the Amazon and Paraná-Paraguay rivers, future development represents a significant threat to the cost-competitiveness of American exporters. State-owned Chinese companies are investing in facilities along river systems, but environmental backlash and lack of coordination

can limit growth. China's investments in intermodal facilities on the Yangtze could further enhance its use, particularly connecting to other Chinese cities and to railways that lead to Europe. China's involvement in the Mekong does not appear to prioritize freight shipments, but has clear geopolitical implications. Europe's already-developed systems are not a threat, but can be a model for prioritizing reliability and connectedness on the rivers.

If global investment in waterways-based trade outpaces similar investments in the United States it could have negative implications for economic competitiveness. To the extent that underinvestment in our waterway system makes it more vulnerable to disruption and less reliable in the service of commercial, governmental and military users, there could also be negative implications for national security. Ensuring sustained and smart investment in its inland wateray network is an important part of fulfilling the United States' multimodal transportation objectives.

1.0 Introduction and Methodology

The U.S. marine transport system contributes over $500 billion to the gross domestic product (GDP) and is responsible for approximately ten million jobs, directly and indirectly, throughout the country.[1] The system includes coastal, blue-water, and inland ports as well as the supporting infrastructure, including lock and dam systems, that enable commercial and recreational activities.

The inland waterway component of this system is a critical backbone of the maritime network. Domestic shippers and exporters move over 500 million tons of construction, energy, manufacturing, chemical, and agriculture products annually.[2] Inland waterway transport is a fuel-efficient and cost-effective means to deliver bulk goods, particularly from agricultural and manufacturing production centers in the interior of the United States to both domestic and foreign markets.

The extensive reach of its inland waterways system has helped make the United States the largest trading nation in the world measured in the value of both imports and exports for goods and services. However, the ability to maintain this position depends on a regular assessment of infrastructure needs and development strategies.

Aging lock and dam systems and closures due to unexpected maintenance and repair create bottlenecks throughout the supply chain. Many of these systems are long past their useful age, are costly to repair, and are occasionally unreliable. The system has a $6.8 billion backlog in needed construction projects to help address the 5,000 hours lost due to lock closures between 2015 and 2019.[3]

Trade is global in nature and because inland waterway systems add valuable capacity to the other components of the U.S. transportation network, the current state of inland waterways cannot only be measured against domestic investments in road, rail, and air systems. Comparisons must be made in the context of similar investments in other nations that compete for leadership in global trade.

The 2021 Infrastructure Investment and Jobs Act (IIJA) provides historic levels of investment in transportation infrastructure with potential short-term and long-term benefits to the waterway systems that support the U.S freight network. Understanding where and how to prioritize investments depends upon an understanding of the current state of those systems.

This report focuses on the current state of the U.S. inland waterway system in comparison with others from around the world. It uses case studies of river systems from Europe, Asia, and South America to compare investment levels, commodity flows,

governance structures, and investment priorities. In some instances, the case studies also reveal the impact that competing uses for the system, such as recreational uses or damming for hydroelectric power, have on the capacity to move goods.

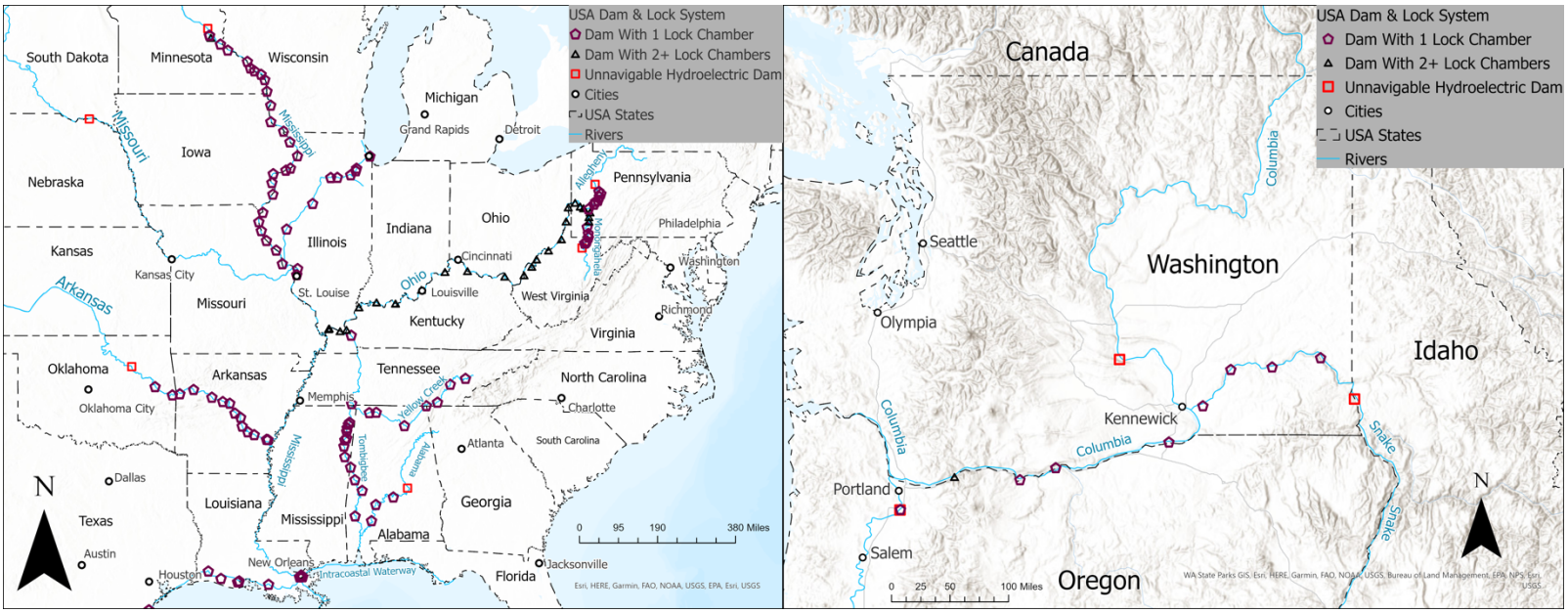
The research relies on publicly available data, government reports, and independent sources from the U.S and case study countries. Comparable information on tonnage numbers, foreign direct investment, and strategies can be difficult to find, so the research team spent considerable time contacting local officials and researchers to gain insights into the operations, plans, and investment in waterways around the world.

2.0 The Role and Function of the U.S. Inland Waterway System

The inland waterway system in the United States is made up of several connected rivers that include infrastructure that enables commercial navigation. The primary part of this system is the Mississippi River, its major tributaries, and connecting canals, including the Gulf Intracoastal Waterway. Unconnected rivers on the system include the Snake River, the Sacramento Deep Water Ship Canal, and the Hudson River. Several other coastal waterways, canals, and bays are part of the marine waterway network, but not part of the inland system. The Great Lakes and St. Lawrence Seaway are treated as separate waterway systems because of their shared border and governance with Canada.

Figure 1 shows the most heavily used portion of the inland waterway network, made up of roughly 12,000 miles of rivers and 237 lock chambers at 192 different locations on the Mississippi, Ohio, Tennessee-Tombigbee Waterway, Illinois, Snake, and connecting rivers and canals.[4] Figure 1 also shows the locations of non-navigable dams, demonstrating the limited navigability of the systems. Much of this area extends through the Midwest and the Gulf Coast connecting the two regions, linking import and export channels and facilitating commerce.

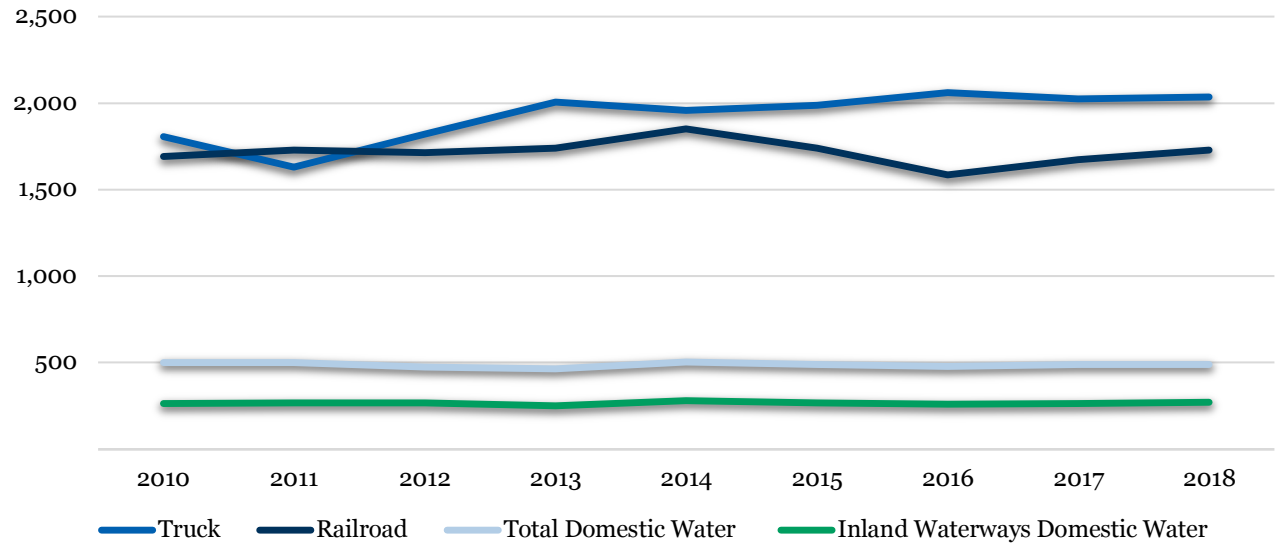
Figure 1: U.S. Inland Waterway System, Select Rivers



Sources: United States Army Corps of Engineers, 2022; National Weather Service, 2010; Esri Data and Maps 2021; Google Maps Satellite Images 2022.
Full interactive map here: https://arcg.is/ovvrCW

The U.S. inland waterway network of channels, locks, dams, towboats, and barges carries about 260 billion ton-miles of freight annually, accounting for approximately five percent of the nation's freight, shown in Figure 2, including shipments on the Gulf Intracoastal Waterway.[5]

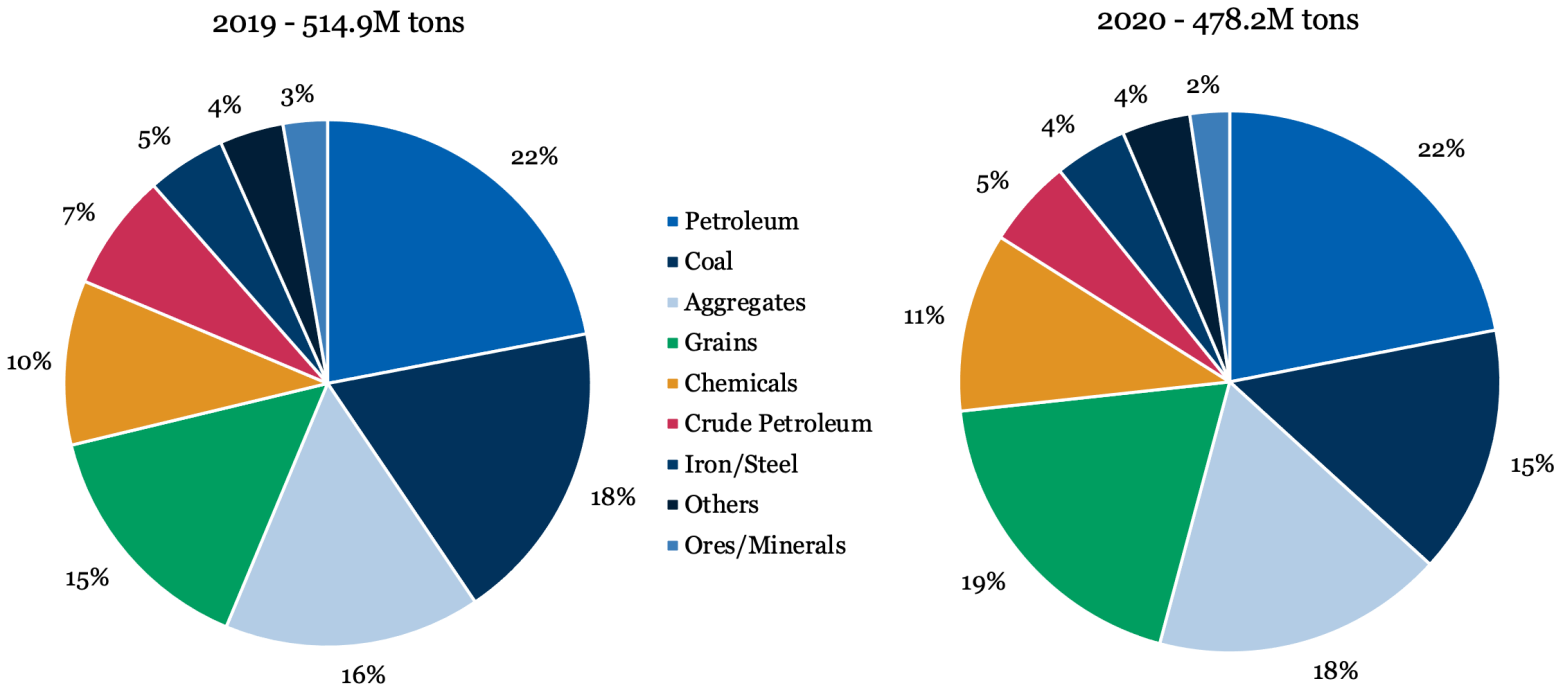
Figure 2: U.S. Ton-Miles of Goods Movement from 2010-2018 (billions)



Source: Bureau of Transportation Statistics, 2019.
Note: air and pipeline shipments not shown on the graph

The inland waterway segment of the supply chain supports more than 540,000 jobs and moves over 500 million tons of freight each year, which is valued at $229 billion.[6] Freight activity on inland waterways, as shown in Figure 3, includes petroleum products, aggregates, coal, and grains — accounting for five percent of total commercial tonnage shipped in the United States. Tonnage dropped from 2019 to 2020, coming primarily from decreases in energy shipments, but was partially offset by increases in grain. The inland waterway system rarely moves high-value goods or containerized freight, partially due to the need for fast shipping times, something inland waterways cannot offer due to the need for inland transloading.

Figure 3: U.S. Inland Waterway Traffic, 2019 and 2020



Source: Waterborne Commerce Statistics, 2019 and 2020
Note: does not include lakewise or costal waterway traffic

The barges moving freight along U.S. inland waterways outperform trucking and rail using multiple metrics. On a per-ton basis, barges have significantly fewer incidents of injuries, fewer hazardous materials spills, and fewer emissions per ton than both rail and highway trucking.[7]

The U.S. inland waterways system is also important for national defense. For example, the waterways are used to transport commercial and military booster rockets, which are too large to travel on other modes of transportation, from Northern Alabama and other locations to launch sites.[8] Nuclear research and reactors are strategically placed along the waterways.[9] The military also uses barges to efficiently transfer equipment between bases, including critical parts and supplies to support military shipbuilding.[10]

A reliable waterway system also depends upon a reliable workforce that makes possible the flow of goods on the waterway and their transfer to landside connections, and is one reason why *who* moves the goods is often the subject of national transportation policy. In the United States, transportation within the nation's borders is governed by the Merchant Marine Act of 1920, also known as the Jones Act, which requires that waterborne cargo which is transported domestically in the United States be moved on

vessels that are US-built, US-owned, and US-citizen crewed. These laws and regulations are designed to not only help bolster local workforces but also to ensure continuity of service independent of external economic and political forces.

The U.S. inland waterways system is maintained by the United States Army Corps of Engineers (USACE). USACE receives annual appropriations from Congress for maintenance and operations on the inland and coastal waterway system. The costs of construction and major rehabilitation come from the Inland Waterways Trust Fund (IWTF, supported by a 29-cent per gallon barge fuel tax) and general fund appropriations.[11] In FY2020, USACE spent $1.29 billion for operations, maintenance, channel stabilization, and new construction, of which $113 million came from the IWTF. The private sector contributes as both a USACE contractor for construction, operations and maintenance, as well as an operator of services and private port facilities on the waterways.[12]

Traditionally, new construction was funded half by the proceeds from the IWTF and half from general fund appropriations, amounting to about $200 million per year on average. Since 2014, Congress adjusted the cost-share and increased general fund outlays substantially to address the growing backlog of construction and rehabilitation needs on the system, bringing the annual construction totals to close to $400 million annually.[13] USACE also typically spends about $900 million annually on maintenance and operational activities, including channel dredging.

Prioritizing and targeting investments is a joint effort by USACE and Congress. USACE maintains a Capital Investment Strategy that is used to identify possible construction projects, and Congress often sets the investment priorities by listing the projects to be funded in annual appropriations, indicating that the strategy has a political dimension to it.[14] USACE is responsible for allocating the operational and maintenance spending, but a 2018 report found deficiencies in the USACE approach to tracking deferred maintenance, limiting its ability to manage assets and communicate needs to members of Congress.[15] A 2015 report found that the U.S. inland waterway system lacks a system reliability plan to allocate limited navigation resources.[16]

Significant new resources to address construction and maintenance backlogs arrived with the passage of the Infrastructure Investment and Jobs Act (IIJA) in 2021. Under the IIJA, the USACE received $2.5 billion dedicated to construction and rehabilitation projects on the inland waterways and an increase in annual operations and maintenance support throughout the life of the law.[17] Inland port infrastructure projects are also eligible to receive funding under a competitive grant program, the Local and Regional Project Assistance Grants (RAISE).

In March 2022, USACE released an updated plan for programming most of the IIJA's $2.5 billion. The program fully funds new lock programs, in Table 1, addressing some of the most pressing construction and rehabilitation needs that USACE has identified.[18] These projects are in addition to the four ongoing major inland waterways projects USACE is currently undertaking: Olmsted Locks and Dam on the Ohio River; Locks and Dams 2, 3 and 4 on the Monongahela River; Kentucky Lock and Dam on the Tennessee River; and Chickamauga Lock on the Tennessee River.

Table 1: Army Corps of Engineering Construction Account – Projects under IIJA

State	Project	Funding (Millions)
Arkansas	Arkansas River Three Rivers Improvement Project	$109.1
Arkansas, Oklahoma	McClellan-Kerr Arkansans River Deepening	$92.6
Illinois	T.J. O'Brien Lock & Dam, Illinois Waterway	$52.5
Illinois, Missouri	Lock and Dam 25 - Upper Mississippi River	$732.0
Kentucky	Kentucky Lock and Dam, Tennessee River (additional funding to ongoing project)	$465.5
Pennsylvania	Montgomery Lock and Dam, Upper Ohio River	$857.7
Pennsylvania	Emsworth Lock and Dam, Upper Ohio River	$77.0
Total		**$2,386.5**

Source: USACE Capital Investment Strategy 2022

New investment in replacing or rehabilitating aging waterway infrastructure is a welcome sign for current and future barge operators. Unscheduled and scheduled closures have been significantly reduced in recent years, with only 5,000 hours of closures between 2015 and 2019, compared with almost 18,000 hours in the 2010-2014 period.[19] While the increased investment levels represent a significant improvement, the system is still susceptible to major delays. For example, in 2019 an unplanned closure of the Bonneville Lock system on the Columbia River forced barge traffic to stop on the entire river for three weeks.[20] Continued quality maintenance practices can curb unforeseen closures.

In part due to the river locations, extra handling costs, slower trip times, and variable water levels compared with other modes, containerized freight on the inland system has never been widely embraced by private shippers. However, the America's Marine

Highway Program (AMHP), a grant program managed by the U.S. Maritime Administration (MARAD), has funded more than $33 million in grants to support container-on-barge services directly intended to divert highway traffic. The program has supported services between Memphis and New Orleans on the Mississippi River, between Richmond and Hampton Roads on the James River, and other intracoastal container services.[21] These services, supported through the federal grants, have successfully diverted thousands of truckloads of freight, but the private sector is not currently providing unsupported services.

The future of freight flows on the river system is also threatened by changing demands for goods. While coal and petroleum (including liquid bulk petroleum and petroleum products) represent the two largest commodity groups, national energy priorities include decarbonization and a shift to cleaner fuels. Use of the waterways for trade is also threatened by competing priorities which include demand for water and landside investments that support recreational uses, including recreational boating.

3.0 Evaluation and Comparison of Globally-Important Inland Waterway Systems

To better understand the state of U.S. inland waterway systems and to use that understanding to inform policy, this report reviews globally-significant waterway systems from around the world. These case studies review the current and historical state of the system, including a review of available data and information on traffic volumes and investment levels as well as system governance, administration, and future plans. The findings and lessons help in the assessment of the competitiveness of U.S. inland waterways and the effectiveness of U.S. inland waterway policy.

To select the rivers in this study, the research team reviewed the most heavily trafficked rivers from around the world, looking at rivers with both the highest navigation levels and the highest new investment levels. This initial review included the following rivers:

South America
- Amazon
- Magdalena
- Orinoco
- Paraná-Paraguay

Africa
- Nile

Asia
- Mekong
- Yangtze
- Ganges

Europe
- Rhine
- Danube
- Volga
- Dnieper

The river systems selected for more in-depth analysis were:

- **Amazon and Paraná-Paraguay in South America** – The Amazon provides a naturally navigable waterway with significant development potential. The Paraguay River is the most developed and, until recently, the most heavily used river in South America. The varying historical investment along with foreign private sector involvement and interest make it a valuable comparison to the inland waterway system in the United States.
- **The Rhine and Danube in Europe** – These rivers, and their connecting canal, are the busiest on the European continent. In recent years the Rhine has been strategically leveraged to move containers and other high-value goods in and out of France, Germany, and Switzerland. Its coordinated structure and multiple jurisdictions make it a compelling case from a governance and strategy standpoint.

- **Yangtze and Mekong in Southeast Asia** – The Yangtze flows through China's industrial and farming heartland and is the busiest freight waterway on the planet. China's national economic strategy drives investment on the Yangtze that affects global trade. While on the Mekong there is limited navigability and hence low freight levels, China's investments on the river have geopolitical implications downstream for Cambodia, Vietnam, Laos, and Thailand.

The cases are presented in this section, beginning with a comparison in Table 2. Where possible, every attempt was made to standardize units of analysis including the use of dollars where investments are identified. The presentation of data, however, reflects its availability and the challenge of verifying its accuracy through multiple sources. Data from national and European Union sources were more readily accessible and consistent than the data from South American and Chinese and Asian sources. Confirmation of data from the latter two cases often involved reports from third parties such as the Asian Development Bank or World Bank. In some instances, units of measurement and reporting periods differed. In other instances, the analysis covered different river segments. Data sources are further explained in the cases where warranted.

Illustrative maps are provided for each case study. An interactive map for all three cases and for the U.S. inland waterway system can be found at https://bit.ly/EnoWaterways.

Inland Waterways and National Security

This report is primarily interested in how inland waterways in the United States and abroad play into U.S. economic competitiveness. Economic competitiveness becomes closely tied with national security as foreign companies or governments are increasingly interested in investing in global port and supply chain infrastructure, particularly in developing countries. The case studies selected and the analysis of them includes a discussion of foreign direct investment, particularly from China (when applicable) as it relates to national security. Economic competitiveness *is* national security, and investments in the U.S. domestic waterway network act as a strategic investment.

Table 2: Comparison of River Systems

	U.S.	Asia		Europe		South America	
		Yangtze	Mekong	Rhine	Danube	Amazon	Paraná -Paraguay
Annual tonnage	515 million tons (2019)[22]	2.69 billion tons (2018)[23]	128 million tons in Mekong River Delta in Vietnam (2018)[24]	160 million tons (2020)[25]	60 million tons (2019)[26]	25 million tons (2019)[27]	20 million tons (2018)[28]
Tonnage growth rate	+1.4% from 2018 to 2019[29]	+ 8.2% from 2016 to 2017[30]	+ 6.4% annually from 2007 to 2014[31]	- 11% from 2017 to 2018, -8.4% from 2019 to 2020[32]	- 1.4% from 2019 to 2020[33]	+ 6.7% annually from 2010 to 2019[34]	+ 4.5% annually from 2010 to 2018[35]
Number of navigable lock/dam systems	237 lock chambers at 192 locations on entire inland waterway system	2 Dams with 2+ Lock Chambers 1 Dam with 1 Lock Chamber	1 dam with 1 Lock Chamber within China 1 dam with 1 Lock Chamber in Laos 9 Unnavigable Dams	11 Dams with 2+ Lock Chamber 1 Dam with 1 Lock Chamber *Canal and Elbe River between Rhine-Danube: 8 Dams with 2+ Lock Chambers 42 Dams with 1 Lock Chamber	14 Dams with 2+ Lock Chamber 4 Dams with 1 Lock Chamber	No dams or locks on the Amazon Estimated 158 dams across tributaries.	Paraná River: 3 Dams with 1 Lock Chamber 5 Unnavigable Dams The Paraguay River has no dams.
Extent of navigability	12,000 miles of commercially active inland waterways[36]	1,700 miles[37]	340 miles[38]	500+ miles[39]	1,498 miles[40]	900 miles for large ocean ships, 2,250 for smaller ocean vessels.[41]	1,678 miles[42]
Commodity types	2016:[43] - Coal - Petro & Petro Prod - Chem & Rel Prod - Crude Materials: - Primary Manuf Goods - Food & Farm Prod - All Manuf Equip	2014:[44] - Metal ore - Coal - Mine construction - Nonmetallic ore - Chemical raw materials and products -Light industry and pharmaceutical products - Machinery, equipment	2018:[45] - Petroleum - General cargo -Cement - Steel - Coal - Fertilizers - Agriculture products.	2020: - Mineral oil products and sands/stone/gravel comprise around half of commodities - Chemicals, iron ore, agribulk/food products, coal, and metals are also transported in significant numbers.[46]	2020: - Iron ore, metal products, steel/coal comprise 45-55% of commodities- Food products are also transported in significant numbers.[47]	2019: 8 million tons of soy, 8 million tons of cereals, 3 million tons of minerals and oil are transported in the upper part of the river. Coffee, cacao, and logging industries also use the waterway.[48]	Paraguay: soybean, grains, petroleum, steel, minerals, oil, manufactured products, ore, Bolivia: soy, sunflower, flax, cotton, wheat, iron, and manganese. Uruguay: dry bulk, soybean Argentina: grains, soybean, and oils. Brazil: soybeans, ore

3.1 South America

The South American continent has several navigable rivers that are significant to the region's internal and export-based trade. By all measures, the largest river system is the Amazon and its tributaries. It is naturally navigable and while it does not have large traffic flows compared to other global rivers, these are increasing quickly as the economy and population grow in the region. The second most used system in South America is the Hydrovia Parana-Paraguay (HPP), where those two rivers enable export and import access from Brazil, Paraguay, Argentina, and Bolivia. This section focuses on those two systems, including the regional and international investments to enhance their use. Other important rivers, including the Orinoco and Magdalena rivers in the northern part of the continent, have attracted significant investment, including a $1 billion iron ore facility on the Orinoco supported by the Chinese government.[49] But these rivers have much less investment and overall potential compared with the Amazon and HPP.

3.1.1 Amazon River

The Amazon River is approximately 4,250 miles long and has over 1,100 tributaries that branch off from the main river or the Amazon proper, as shown in Figure 4.[50] The river originates in the Andes Mountains of Peru and runs laterally through the South American continent in Brazil, Colombia, Venezuela, Ecuador, and Bolivia. Major tributaries include the Huallaga, Ucayali, Marañon, Negro, Xingu, Madeira, Purus, Tocantins-Araguaia, and Japura rivers. The Amazon River upstream from Manaus, where it meets with the Negro River, is also known as the Solimões River. The river traverses tribal lands and 27 state borders containing rainforests, mountains, grasslands, savannas, dry forests and shrublands, and pastures.[51]

Figure 4: Amazon River System

Sources: United States Army Corps of Engineers, 2022; National Weather Service, 2010; Esri Data and Maps 2021; Google Maps Satellite Images 2022.
Full interactive map here: https://arcg.is/ovvrCW

Although there are dams on many of its tributaries, there are currently no dams or locks on the Amazon proper which gives the river natural navigability.[52] The river can also naturally accommodate deep draft ships in its lower sections. Brazil's agricultural and industrial sectors have proposed infrastructure projects that would lead to the construction of lock and dam systems because the flow of the river has potential to generate significant hydroelectric power. The future of these projects remains uncertain because such projects are generally unpopular and opposed by environmental agencies

and indigenous groups concerned about the potential impact on surrounding communities and biological diversity.[53]

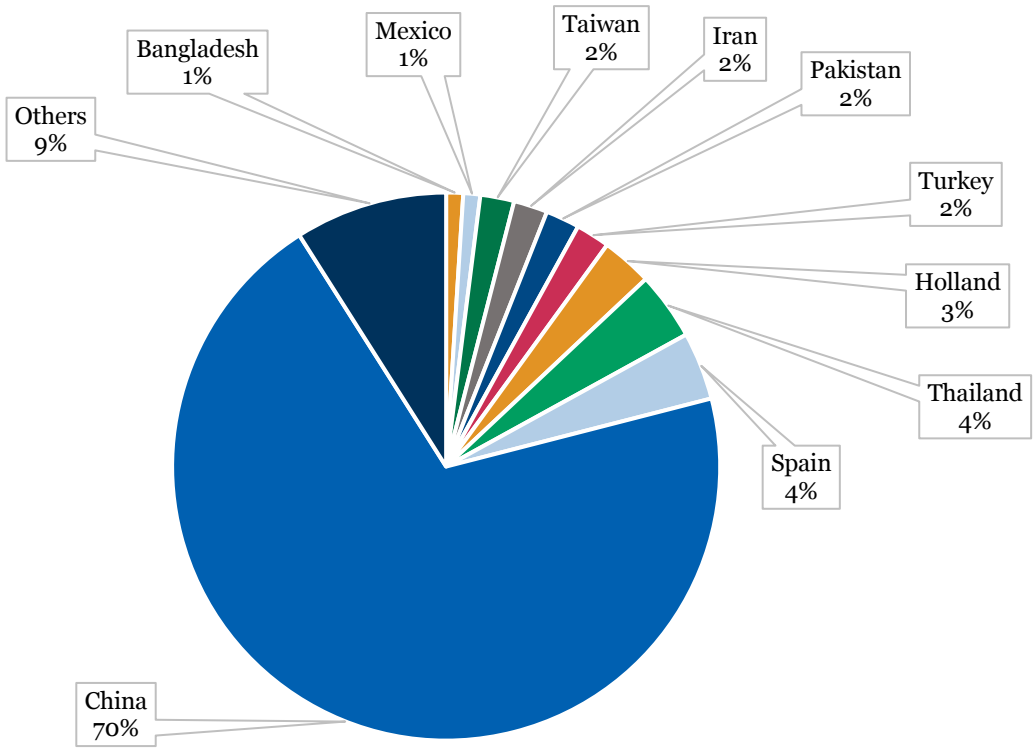
Commodity and Freight Flows

The Solimões-Amazonas waterway (herein referred to as the Amazon River) accounted for nearly 25 million tons of cargo in 2019. If the Madeira River and Tocantins-Araguaia Rivers (the major tributaries of the Amazon) are included the total tonnage moved is about 44 million tons. Goods movement on these three main waterways is increasing rapidly: only 13 million tons moved on the Amazon, Madeira and Tocantins-Araguaia rivers in 2009, a 235 percent increase over 10 years.[54]

Soy and cereals make up most of the cargo transported on the Amazon, with soy at approximately 7.8 million tons and cereals at 7.2 million tons, followed by fuel and mineral oils at around 3.4 million tons.[55] The river is also used to transport goods that support the development and use of thermoelectric power plants.[56] Other goods moved on the Amazon include other grains, coffee, cacao, and logging.[57]

Soy (soybeans and soybean meal), maize, carbon, and ethanol are Brazil's main exports.[58] Soybeans, Brazil's leading export, predominantly go to China, and the business of exporting them grew significantly since 2011, from approximately 33 million tons in 2011 to 86.6 million tons in 2021. Current destinations are shown in Figure 5.[59] However, only about 12 million tons of Brazil's 86 million tons of soybean exports leave through a port on or with a connection to the Amazon River or one of its tributaries. [60] The Association of Port Terminals and Cargo Transshipment Stations in the Amazon Basin, also known as *Amport*, believes the river needs improved access to ports and enhanced environmental practices to continue development and inland waterway usage.[61] The vast majority of exports, soybeans or otherwise, arrive at a port facility via truck, or in some cases, train.[62]

Figure 5: Destination for Brazilian Soybeans in 2021



Source: National Association of Grain Exporters, 2021.

Governance and Administration

Although most of the Amazon River is within Brazil, it is a transboundary water resource and its governance requires the cooperation of several countries. The Amazon Cooperation Treaty was established in July 1978 by Brazil, Bolivia, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela.[63] The Amazon Cooperation Treaty Organization (ACTO) was founded in 1996 to strengthen and enforce the treaty, jointly run by the eight countries that signed the treaty. ACTO deals with general Amazonian territories and resources and is not solely focused on or constrained by the governance of the Amazon River or Amazon waterways.

Despite the treaty and ACTO, regulation and investment of the Amazon River basin suffers from a lack of coordination. The intergovernmental decision-making process is slow, burdened by conflicts of interest among the member states, each of which has an independent approach to governing the portions of the river and waterways within its borders.[64]

Within Brazil, there are federal infrastructure regulatory agencies that govern freight flows on the Amazon River. The 1988 Brazilian federal constitution assigns sea, river, and lake port exploitation rights to the federal government.[65] The most important agency is the National Waterway Transport Agency (ANTAQ), established in 2001.[66] ANTAQ was created as a special authority linked to the Ministry of Transport and the Ports Secretariat. It oversees the regulation and supervision of Amazon port and waterway transportation within Brazil, as well as port authorities, privately owned terminals, and shipping companies.[67] ANTAQ is the chief governing agency of the Amazon River in Brazil, while the Brazilian Ministry of Infrastructure, Ports & Civil Aviation (Brazil Mol), which replaced the Ministry of Transport in January of 2019, is responsible for infrastructure provision and oversight at the national level. The director of ANTAQ leads the "Waterway Dialogues," a series of meetings that have been held since 2017 with the support of Brazil's Agency for Sustainable Development to discuss the development of logistics infrastructure in the nation's rivers.[68]

Port management in Brazil involves a mix of public and private operators.[69] This includes publicly managed ports overseeing all areas of infrastructure and operation; ports with public management of the infrastructure but with private port operation; and more traditional landlord ports that have public infrastructure and private superstructure and port operation.[70] The majority of Brazil's 175 ports are private, while other ports include a mix of private and government investment.[71]

Cabotage on the Amazon is regulated by Brazil's recently published Law No. 14,301/2022, known as the Cabotage Transport Stimulation Program. Also referred to as BR do Mar, the law establishes a set of qualifications for Brazilian Shipping Companies (EBNs) to transport by cabotage, including authorization as a Brazilian Shipping Company (EBN), compliance with federal taxes, and the submission of operations information. The law also allows EBNs to charter a foreign vessel without the burden of maintaining their own fleet. Additionally, vessels allowed to engage in cabotage transport are not required to register an import declaration and enjoy relief from several federal taxes on imports, foreign goods, and fuels.[72] There are no fuel tax or access charges for use of the Amazon River.

Funding and Future Plans

Navigation on the Amazon River does not require significant levels of investment because the river is naturally deep and wide, allowing for seagoing vessels to access the waterway without locks or dredging. Plans to modify the waterway are motivated by the potential for large amounts of hydroelectric power.[73] Damming projects face environmental opposition, stalling significant changes to the Amazon River. From a

freight standpoint, investment in waterways is significantly less of a national priority when compared with investment in rail and road transportation.[74]

The management, development, and investment in inland waterways, including the Amazon and its tributaries, is handled by the national government through ANTAQ. Private investment, whether foreign or domestic, is confined to ports and does not usually include investment in inland waterways, including projects such as dredging. Currently, the legal framework does not allow for private investment or management of inland waterways, regardless of potential interest from private agencies.[75]

Private companies, including foreign entities, invest in the development and improvement of ports along the Amazon proper.[76] In the portion of the Amazon River that runs through Brazil, Brazilian companies, especially in the soy industry, demonstrate interest in working with foreign investors to develop more port facilities and routes.[77] Foreign investment comes from private companies in the United States and Europe, and state-owned and private enterprises in China.[78]

The Amaggi Group, Brazil's biggest soy producer and a commodities transport company, is involved in the creation of river ports and industrial complexes, especially around the city of Itaituba, located on a major tributary of the Amazon River. Bunge Limited, an American agribusiness company and international soybean exporter, has also been a notable investor in grain port facilities over the last decade. Further, China purchases the majority of Brazilian soybeans, and has a growing demand for soy. COFCO, a Chinese state-owned food processing and agribusiness company, is one of the main clients of Hidrovías do Brasil, a Brazilian bulk transportation and logistics company. COFOC operates its own fleet of dry bulk carriers. COFCO is one of Asia's leading agribusiness groups, with investments in warehouses, processing plants, and port terminals in Brazil and in other parts of Latin America. COFCO has stated its plans to continue investing in Brazil, and in 2019 was considering building a rail line that connects to northern Brazilian ports on the Amazon.[79]

Peru maintains sovereignty over a system of waterways that often serve as the main thoroughways in the many regions of the country that lack roads.[80] In Peru, there is some foreign interest in transforming the waterways, but projects must be coordinated through the Peruvian government.

The Amazon Waterway Project, known in Peru as the Hidrovía Amazónica, was first proposed in 2014 in order to address dredging needs at 13 shallow river locations where eight feet of depth will allow for year-round navigation. It is a $95 million project and if completed would open approximately 1,670 miles of the Huallaga, Ucayali, Marañon, and Amazon rivers for navigation in Peru.[81]

Peru's Ministry of Transport is continuing with environmental studies.[82] In 2019, the project was the subject of an environmental impact assessment that was largely conducted by Peru's environmental certification service (known as SENACE) with input from other national environmental agencies, such as SERNANP, Peru's national parks service. A brief report from January 2020 states that the project was suspended but remains on the table. While the Ministry of Transportation and Communication would like the project to continue, its future depends on the outcome of environmental assessments and the availability of national funding.[83] Most recently, the project has been stalled in the environmental process due to opposition from environmental advocates and indigenous groups – it is unclear if the project will ever proceed.[84]

In Brazil, the federal government has demonstrated interest in industrializing its waterways and increasing the flow of goods. However, this rapid industrialization has created conflicts between the state, business interests, and local indigenous populations supported by global environmental groups. As of 2017, there were plans to increase usage of the Tapajos River, a major tributary of the Amazon, and build 49 major dams along the river including its own tributaries. The project was opposed by several groups, including the Indigenous Missionary Council, International Rivers, Amazon Watch, and Greenpeace. Opponents of the project believe that environmental impact studies have been inadequate, and have expressed concern about habitat loss, social problems and negative impacts on local communities, and accelerated deforestation.[85]

3.1.2 Paraná-Paraguay Rivers (Hidrovía Paraná-Paraguay)

The Paraná River and its main tributary, the Paraguay River, jointly form an approximately 2,200-mile-long navigable waterway referred to as the Hidrovía Paraguay-Paraná (HPP) as seen in Figure 6.[86] The Uruguay River, which has 250 miles of navigability in the lower section and connects to the HPP via the River Plate estuary, is sometimes included in freight statistics.

The HPP waterway runs through or borders five South American countries: Brazil, Argentina, Paraguay, Uruguay, and Bolivia. The Paraná River consists of two navigable sections. The lower part of the river connects with the Paraguay River and Atlantic Ocean up to the Itaipú Dam, which is the second largest hydroelectric dam in the world. The Itaipú Dam does not include locks, so it is impassable for freight. The upper parts of the Paraná River include several navigable locks and dams, including several on the Tiete River, which serve domestic waterway shipments wholly within Brazil. The Paraguay River has no dams and connects to the Atlantic Ocean via the lower portion of the Paraná River.

The area south of Santa Fe City, Argentina, about 310 miles, can accommodate oceangoing vessels. Near Rosario, Argentina, close to the Paraná River's mouth, depths

can reach up to 34 feet but become shallower near Santa Fe City at 28 feet. The parts north and upstream of Santa Fe City are referred to as the inland navigation section.[87] River depths on the inland section are typically 13 feet on the Paraná River from Santa Fe to the junction with the Paraguay River, ten feet on the Paraguay River to Corumba, Brazil, and as low as 6 feet on the upper stretches of the navigable portions to Caceres, Brazil.

Figure 6: Hidrovía Paraguay-Paraná River System

Sources: United States Army Corps of Engineers, 2022; National Weather Service, 2010; Esri Data and Maps 2021; Google Maps Satellite Images 2022.
Full interactive map here: https://arcg.is/ovvrCW

The Paraná River and its tributaries have 54 dams in total, including the unnavigable Itaipú dam and the navigable Yacyretá dam. Both dams produce significant hydroelectric power, with the Itaipú built in 1984 and the Yacyretá built in 1994. Maximum drafts of up to 12 feet on the Yacyretá Dam create complications, and they are seldom used. Barge convoys would need to be split and reassembled, presenting a logistical challenge, and adding significant cost.[88] While most of the dams were built for power generation, some dams in the upper Paraná River in southern Brazil were built in the 1970s to allow water to be released from reservoirs during times of drought.[89] The river has also been dredged, and in September 2021 the Argentinian government authorized funding for new dredging efforts, including widening the river channel to 328 feet in some areas.[90]

The Paraguay River has no dams or locks, which helps keep infrastructure costs low but presents a challenge to managing water levels. The International Trade Administration notes that the portion of the river that is in Paraguay needs significant investment and infrastructure improvements in these areas to help manage variable water levels.[91]

Commodity Data

Bolivia, Argentina, Brazil, Paraguay, and Uruguay use the HPP to transport goods. For the landlocked countries of Bolivia and Paraguay, the HPP is the only water-based means of export or import.[92] The waterway carries almost 80 percent of Paraguay's total foreign trade. Paraguay transports soybean, petroleum, steel, minerals, manufactured products, ore, oilseeds, oils and by-products, and grains primarily to other South American economies but also has significant trade with Russia.[93] Bolivia relies heavily on overseas commerce as well, and transports soy, sunflower, flax, cotton, wheat, iron, and manganese.[94] Uruguay is involved by receiving dry bulk commodities, including soybeans, from upstream countries to transfer freight to oceangoing vessels.[95]

Argentina uses the HPP for multiple purposes: moving domestic dry bulk; transferring freight to oceangoing vessels; receiving freight, often soy, ore, and iron from upstream countries for processing and manufacturing; and bringing in Bolivian and Paraguayan imports, often wheat and fuel. Argentina mainly transports grains, soybean, flour, biodiesel, and oils on the HPP.[96]

Above the Itaipú Dam, the Paraná and Tietê Rivers run through Brazil's agricultural heartland, and the waterway transports oilseeds, sugar cane, fertilizers, and grains to transfer to export terminals, often upstream via truck to ports near Sao Paolo.[97] Over two million tons of internal shipments were transported on the Tietê-Paraná waterway annually from 2010 through 2018, with a significant drop in 2020 due to a persistent drought that is causing issues in navigability due to falling water levels.[98]

Governance and Administration

The five HPP countries established several agreements and organizations to govern the waterway. In part to manage investments in hydroelectric dams, including the Itaipú Dam where construction began in 1970, the region signed the Intergovernmental Coordinating Committee of the Countries of La Plata Basin (CIC) in 1967 and the Treaty of La Plata Basin in 1969.[99] In 1989, the countries created the Intergovernmental Committee of the Hidrovía Paraná Paraguay (CIH) to increase collaboration, identify and prioritize projects, and develop intergovernmental regulations.[100] In the 1990s, the CIH incorporated the Waterway Transport Agreement into the Treaty of La Plata Basin, which helped establish protocols and a common navigation code.[101]

For the portion of the Paraná River that flows along the Paraguay-Argentina border, authority is split between the two governments. A 1971 agreement between the two countries resulted in the Joint Commission of the Paraná River (COMIP), a bi-national entity. Its responsibilities include assessments regarding water use and development, including ownership and management of the Itaipú and Yacyreta dams. It operates with two separate in-country headquarters which have at least one representative from the other country to facilitate the direct exchange of information and communications.[102] There does not seem to be a similar organization for the Paraguay River apart from those described for the HPP.

The national governments of Argentina, Paraguay, Brazil, Uruguay, and Bolivia are largely in charge of their respective sections of the HPP.[103] The nations differ in their legal frameworks and in the structure of their governing authorities, as well as in the amount of autonomy given to municipal levels of government. Investment in Brazil comes mostly from the national government. Similar to the management of the Amazon River and its Brazilian tributaries, the management and investment planning for the HPP are handled by Brazilian federal agencies. These include ANTAQ and the Ministry of Infrastructure.[104] Brazil does not allow direct private investments in dredging, although companies can invest in port construction.

Paraguay has a public-private partnership (P3) model and encourages the involvement of private companies and private investment in the development of the HPP within its borders. The Government of Paraguay considers the waterway a priority and seeks to improve its infrastructure with projects involving dredging, deepening riverbeds, constructing more ports, increasing vessel capacity, and overall improvements in navigability and safety.[105] The Ministry of Public Works and the government's public contracting office advertise tenders on their official website, and Paraguay's National Directorate for Public Contracts (DNCP) manages all public procurement tenders. Their promotion of public-private partnerships is fairly new: the Ministry of Public Works launched its first P3 in 2019. After that project, proposals were in the works for a

dredging project on the Paraguay River.[106] A 2021 project with Belgian dredging firm Jan De Nul would result in the dredging of over 300 miles of the Paraguay River. The project was in the advanced feasibility study stage as of September 2021.[107]

Paraguay's Public Contracting Law states that foreign firms can bid on international or national tenders through local legal representatives. However, Paraguayan law gives preference to locally produced goods and local companies in public procurements that are open to foreign investors. Besides several P3s in progress with local Paraguayan private companies, Paraguay has agreements with the four other nations on the HPP for trade facilitation, including free trade ports and warehouses, trans-shipment, and storage of merchandise.[108] As of 2014, Paraguay's executive branch can form direct agreements with the private sector without congressional approval, and the Paraguayan government is making efforts to increase transparency and reduce risk and corruption in procurements by managing information through a web-based system hosted by the DNCP.[109]

In Argentina, investment decisions and maintenance are often conducted at the provincial level with significant private sector involvement, under contract, for dredging and maintenance. [110] In 2021, the administration of the HPP in Argentina was reformed, giving more direct authority to the national government. The General Port Administration Agency now handles decisions about maintenance and infrastructure, such as dredging.[111] Previously, administration of the HPP in Argentina was mainly in the hands of Jan De Nul and its Argentinian partner, Emepa. Though these companies did not have ownership in the waterway, they have exerted significant control over decisions concerning dredging and waterway management since 1995.[112]

The HPP faces significant governance and administration challenges as a result of fragmentation and insufficient policy coordination. For example, by the 2010s, only a portion of the CIH countries had ratified proposed common regulatory frameworks. According to the World Bank, investment costs required for improvements to the HPP are relatively low, especially compared to the infrastructure costs of road or railway projects. Rather, barriers to investment opportunities lie in international coordination and the ineffective institutional frameworks of each country.[113] The World Bank describes issues including:

- Administrative delays
- Disagreement between Bolivia and Brazil over Bolivia's access to the Tamengo Canal, a short waterway that flows primarily through Brazil to connect Bolivia to the Paraguay River
- Disputes between the countries over restrictions on Uruguayan vessels traveling through the HPP (which it does not directly border)[114]

For example, the World Bank analyzed a dredging project that was important to both Bolivia and Paraguay, but noted that each country had "completely abandoned" the Intergovernmental Committee of the Hidrovía Paraná Paraguay (CIH).[115]
A more recent 2021 report confirms that the different approaches taken by the HPP countries regarding safety regulations and labor river system.[116] Discrepancies in governance have limited the development of large infrastructure projects, especially when there are concerns about the impact a project may have on the environment. Restrictions and regulations can vary even within a single country, as is the case among the provinces of Argentina. The province of Entre Rios in Argentina banned the construction of dams to block the construction of the Paraná Medio dams, yet the ban does not apply to other provinces in the Paraná basin. This has led to proposals for the construction of more dams upstream in addition to the dams already present on the upper Paraná.[117]

No taxes or fees are charged for navigation on the HPP, and cabotage across all transportation modes, is generally restricted on the HPP and limited solely to national transport enterprises. This creates the overall effect of increased inefficiency due to empty movements, as, for example, when a Paraguayan vessel is unable to transport any cargo between two Argentinian ports. Generally, Latin America lacks a macro-level or regional regulatory framework for cabotage services.[118] However, Brazil's recent Law No. 14,301/2022, known as the Cabotage Transport Stimulation Program (discussed in Section 3.1.1), may signify a shift in favor of expanding cabotage services.

Influences of Foreign Direct Investment

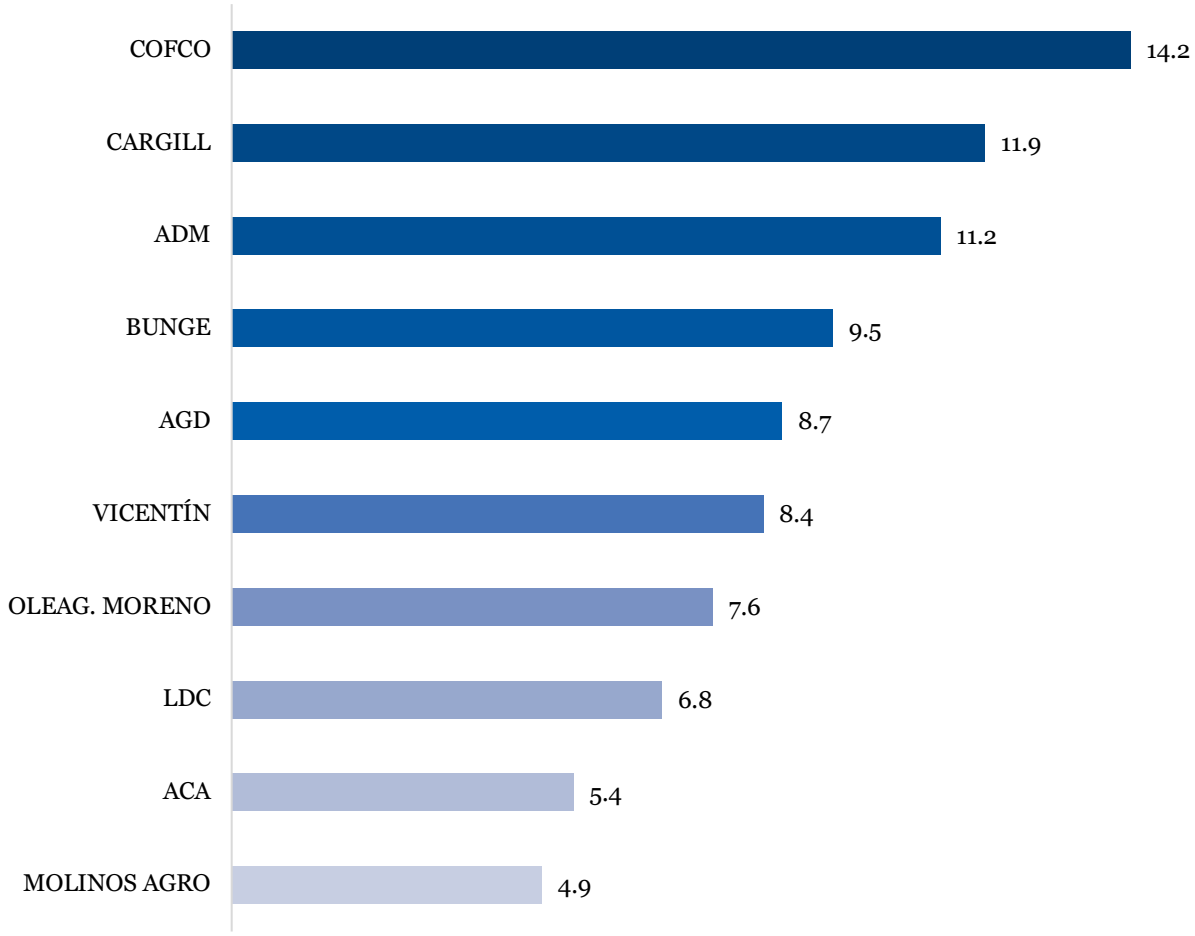
In Argentina, foreign direct investment (FDI) has played an influential role in the management of the HPP. A concession regarding the maintenance of the river system was granted by the government to an alliance between Jan de Nul and a partner Argentine infrastructure company.[119] The alliance is often referred to as Hidrovía SA or Hidrovía Sociedad Anónima. Hidrovía SA held concession of the HPP from 1995 until 2021, at which time the Argentinean government centralized the administration of the HPP and granted authority to its national port agency. This ended the contract between the Argentinian government and Hidrovía SA.[120]

Before centralization, entities from five countries expressed interest in bidding for future concessions, including Jan De Nul, this time without its Argentine partner company. Other interested firms included Van Oord, a Dutch dredging company; Boskalis, a Dutch dredging and maritime infrastructure company; a Belgian company called Dredging International; and Shanghai Dredging Company.[121] The government has stated that there is a possibility of new long-term international concessions in the future. Additionally, it is worth noting that though Argentina has centralized the *administration* of its ports, the day-to-day operations will most likely be carried out by

contractors, rather than the state itself. Thus, the concrete implications of this decision remain unclear.

Chinese companies, such as a subsidiary of China Communications Construction Company (CCCC) known as the Shanghai Dredging Company, have their own ports, vessels, and dredgers in the waterway.[122] China's largest food manufacturer and trader, COFCO, became the largest grain exporter in Argentina as of 2018, transporting the majority of its exports through the HPP. Figure 7 displays the top exporters of agricultural products in Argentina in 2018 and 2019. Notably, the top three exporters are foreign, including U.S. based Cargill and ADM.[123]

Figure 7: Top exporters of Argentine Agricultural products, 2018-2019 (million tons)



Source: Profeta, 2020

Future Plans and Threats

A report from 2015 describes strong lobbying from the agricultural sector for an extension of the HPP to the Pantanal, a tropical wetland area that spans Brazil, Paraguay, and Bolivia.[124] Although the expansion project has already been initiated in the lower part of the Paraná River, it has yet to obtain complete approval or political support due to environmental backlash from indigenous organizations.[125]

The Paraná River is currently experiencing a drought and reduced water levels.[126] The river is at its lowest water level since the 1940s, upending ecosystems and making the transport of commodities extremely difficult.[127] In April 2021, the U.S. Department of Agriculture warned that barges must reduce cargo capacities to avoid grounding in reduced water levels in segments in Argentina, Brazil, and Paraguay.[128] Argentina declared a six-month emergency status for the Paraná River in July 2021.[129] As of December 2021, the river was still experiencing shallow water levels, interrupting cargo transport.

3.1.3 South America Summary

The South American cases represent two very different rivers that have implications for the global freight trade. The Amazon boasts a relatively simple governance structure, a naturally navigable channel, and huge growth potential for inland shipments to export agricultural, mining, and industrial products. It has rapidly grown into the busiest inland waterway channel on the continent. This is in part due to the ability for private firms, domestic and foreign, to invest in port facilities while the national government needs to invest or coordinate little to facilitate movement. The long-term role of the Amazon as a major goods waterway depends on Brazil overcoming gigantic hurdles related to environmental concerns and the need to dramatically increase population and industrial output in the Amazon Rainforest.

The HPP has greater potential to serve as a waterway trade corridor because industrial development and major population centers along the rivers already exist. While the Amazon region is developing an agricultural industry, the Paraná and its tributaries cut through the Brazilian farming heartland and already have the lock and dam infrastructure to enable goods movement. The two barriers to significant expansion of its use are the lack of navigability at the Itaipú Dam and the lack of strategic coordination among the five HPP countries. Enabling navigation for the full course of the Paraná and investing in facilities to control water depth could open up significant traffic for export. This would be at a relatively low cost compared to other infrastructure projects but would require coordination and cooperation among the five HPP countries, which currently is limited.

The lack of coordination poses potential risks to individual nations that depend upon access to and passage through other parts of the waterway system. Resolving these institutional issues could make the HPP a more effective way of getting South American exports to market. In the Amazon basin, Brazilian policy with regard to private and foreign investment might provide a model for other nations seeking to increase funding for inland waterway development and operations. However, it may also make it harder to develop a consensus around national priorities, as rapid industrialization and an expanded number of interested stakeholders may create substantial conflicts between government, state, and local/indigenous interests

3.2 Europe

European rivers, waterways, and canals have been important to European commerce for centuries. Europe has several large rivers that serve as freight corridors, including the Rhine, Elbe, Danube, Volga, and Dnieper Rivers, and many connecting canals that increase their usefulness. This case study focuses on two of the busiest rivers in Europe, the Rhine and Danube, and their connecting canal that uses a portion of the Elbe River.

The European Union (EU) and its member states invest in inland waterways with the goal of enhancing competitiveness and providing high-capacity, low-cost, and sustainable transportation. Figure 8 shows how European states utilize the Rhine-Danube River, the largest river and canal system in the EU, for goods movement to and from the continent's interior.

Figure 8: Rhine-Danube River System

Sources: United States Army Corps of Engineers, 2022; National Weather Service, 2010; Esri Data and Maps 2021; Google Maps Satellite Images 2022.
Full interactive map here: https://arcg.is/ovvrCW

3.2.1 Rhine River

The Rhine is by far the most significant river in all of Europe. Over time, it has been used for travel, goods transport, hydropower generation, flood protection, and land reclamation.[130] Over 500 miles of the waterway are navigable, populated by several major ports, including the Ports of Rotterdam, Duisburg, Strasbourg, and Basel.[131]

The river transported approximately 160 million tons and 55 billion ton-kilometers of cargo in 2020 between Basel, Switzerland and its mouth in Rotterdam, the Netherlands. Notably, the COVID-19 pandemic caused an 8.4 percent decrease between 2019 and 2020.

Vessels (of which there are almost 10,000 registered in Rhine countries) carried on average 1,300 tons each.[132] In recent years, newly built vessels continue to push this number higher: the loading capacity of dry cargo ships built in 2019 reached an average of 3,256 tons, while ships built in 2020 have an average capacity of 2,474 tons, with almost a third of the 27 newly built dry cargo vessels having a capacity between 3,000-4,000 tons. In 2020, 54 new tanker ships were placed into service averaging a capacity of 3,793 tons. The Netherlands registered more than half of the newly built vessels in 2020, and, in nearly all vessel categories, maintains the largest share of the Rhine fleet.[133] As further discussed in Section 3.2.3, the EU's liberalization of cabotage laws has enabled broader definitions of the term. For instance, the Central Commission for the Navigation of the Rhine (CCNR) allows vessels with the right to fly either the CCNR or EU flags as Member States to engage in cabotage.[134]

More than two-thirds of all goods transported on European waterways use the Rhine. Much of the cargo is related to steel production, such as iron ore and metal products, as well as other chemicals, mineral oils, and agricultural goods. From the EU member states, the Rhine countries (Belgium, France, Germany, the Netherlands, Switzerland, and Luxembourg) accounted for 78.6 percent of the total inland waterway transport and approximately 99.99 percent of inland waterways container transport, with Germany and the Netherlands responsible for the largest share.[135] Containerized cargo on the Rhine is growing, although it continues to be a relatively small portion of total traffic tonnage at eight percent in 2015.[136]

However, traffic on the Rhine is vulnerable to disruption, partially due to the river system's interconnectedness to European coastal ports. For containerized cargo, delays and bottlenecks in major ports such as Antwerp and Rotterdam can create similar delays, back-ups, and barge queues at river ports. Misaligned barge stowage, discharge plans, and landside container stacking plans compound queues and back-ups down the line.[137]

Structural barriers exist as well. Moving from the Rhine to the Danube through the Main Canal, for example, requires 50 lock movements, considerably increasing the risk of operational interruptions. Shallow water levels due to drought conditions continue to present pressing challenges, and could worsen with climate change.[138] However, despite these obstacles, the Rhine also maintains several advantages, including the density of

industries situated along the Rhine that operate their own port facilities, contributing to consistently high waterway use.[139]

Belgium, France, Germany, the Netherlands, and Switzerland each take responsibility for developing and maintaining the navigability of its respective section of the waterway, and this process is coordinated by the CCNR and authorized by the Mannheim Convention. The Commission facilitates safe passage, the exchange of information regarding hydraulic projects, reporting of obstacles to navigation, and the examination of potential projects that may affect navigability. Additionally, the CCNR contains several operating committees. Among these is the Committee for Infrastructure and Environment, which monitors and investigates navigation issues such as locks, water levels, and physical infrastructure.[140] Each state however maintains significant control over its section of the river and primarily funds its own projects, operations, and maintenance.[141] The CCNR exists predominantly to facilitate discussion, cooperation, and collective governance, rather than as a technical authority on logistics or operations.[142]

In addition to the CCNR, the International Commission for the Protection of the Rhine (ICPR) handles the river's ecological concerns, such as pollution mitigation and flood prevention. Because the ICPR's jurisdiction does not incorporate the Rhine River basin in its entirety, the Coordination Committee was established in 2001 to include Liechtenstein, Austria, and Belgium, in addition to Switzerland's non-binding assistance as a non-member of the EU. The two Commissions work together to achieve the requirements of the European Union Water Framework Directive (WFD), including publishing the first Management Plan for the Rhine in 2009 and the second in 2015. The Plan divides river management into two components, one that is basin-wide and international in nature and one that is at the sub-basin level (Alpine Rhine/Lake Constance, High Rhine, Upper Rhine, Neckar, Main, Middle Rhine, Moselle/Sarre, Lower Rhine, Delta Rhine). Several organizations at the sub-basin level pre-date the WFD and continue to monitor and report on their own areas.[143]

The Rhine has fewer projects and initiatives dedicated to developing its river basin in comparison to other European rivers such as the Danube because it is already developed and most dams already include a full set of locks.[144]

There are other initiatives designed to enhance the system that go beyond improvements to the waterway itself. The Rhine Hydrogen Integration Network of Excellence (RH2INE) focuses on expanding the use of hydrogen in inland transportation in order to bolster zero-emissions efforts and contribute to green corridors. The initial study for the project was funded by Connecting Europe Facility (CEF), an EU effort to fund infrastructure projects at the European level, in

coordination with several ports, the Province of Zuid Holland, and the ministry of Economic Affairs of Nordrhein-Westfalen in Germany.[145]

While each individual CCNR member state bears responsibility for the financial costs related to its own section of the river, a given member state may have several agreements or conventions with other states. In cases where the Rhine functions as a national border, states share waterway costs. The Mannheim Convention also provides for the levying of port fees in order to finance the maintenance of the river system.[146]

3.2.2 Danube River

The large majority—87 percent or 1,498 miles—of the Danube is navigable. Over 70 percent of that stretch has been dredged, connecting the Rhine River in Germany to the Black Sea at the border of Romania and Ukraine.[147] The river is also the location of hydropower dams including Iron Gate I and II, the largest and most significant dam and reservoir system on the Danube, operated by Romania and Serbia.[148] There are 19 dams on the river and several major ports, including the Port of Constanta, which is connected to the river at the Black Sea via the Dunare Canal.

In 2020, the river transported more than 26 million tons of cargo on vessels that typically range between 1,000 to 1,500 tons in capacity.[149] 3,498 total vessels operate as part of the Danube fleet as of 2020, with cabotage rules similar to the Rhine (See Section 3.2.3).[150] Between 45 to 55 percent of the transport consisted of iron ore, metal products, and steel or coal. A rise in the transport of agricultural products partially offset reduced iron ore and metal transport resulting from the COVID pandemic: total transport declined by a mere 1.4 percent from the previous year.[151]

Container transport is almost non-existent on the Danube because most containers moving through the region are transferred by road or rail. Several attempts to increase container transport, some funded on a national level or by the European Commission, have taken place, but without much success. As a result, the Danube lacks a regular operator and maintains infrequent container shipments.[152]

Reports cite barriers to container transport that include excessively high and low water levels, a lack of modernized terminals, and deficiencies in lock maintenance.[153] Low transport speed and low network density, which often creates the need for both road and rail pre- and end- haulage options is another concern.[154] The comparative advantage of the Danube is in its low transport and infrastructure costs, modernized information sharing systems, and few restrictions on nighttime and weekend transport, making it attractive to moving bulk commodities.[155]

In terms of governance, the Danube River Protection Convention (DRPC) of 1994 provides the framework for member states to cooperate on matters within 1,242 miles of the river's basin. This area includes Austria, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Moldova, Montenegro, Romania, the Republic of Serbia, the Slovak Republic, Slovenia, and Ukraine, in addition to the European Union.

Management of the Danube River Basin District occurs at three levels including the international, national, and sub-unit (management entities within a given state) levels. The International Commission for the Protection of the Danube River (ICPDR), established in 1998, is the main authority for the Danube Basin and oversees project planning and coordination efforts at the international level needed to fulfill the WFD. Although several countries, as non-members of the EU, have no legal obligation to meet WFD requirements, some participate in non-binding cooperation. Since its establishment, the ICPDR has undertaken several studies and developed plans, most notably the release of the first Danube River Basin District Management Plan in 2009, which has been regularly updated since.[156]

Several Danube River ports, particularly those outside of Austria and Germany, suffer from outdated, inefficient terminals and intermodal facilities in addition to a lack of connectivity to road and other transportation networks. A decline in overall cargo volumes and quality of service has, however, led to the establishment of the Danube Ports Network (DaPhNE), which seeks to improve the system via port legislation, funding, administration, network formation, and the development of systemwide innovations. DaPhNE has developed pilot projects, such as the port IT community system (implemented in Enns, Austria; Bratislava, Slovakia; and Novi Sad/Smederevo, Serbia) that streamlines logistics processes at the ports.[157] CEF has also contributed $12 million to the only seaport located within the Rhine-Danube Core Network Corridor, the Port of Constanta in Romania, to upgrade the port's signaling system and build a waste collection facility.[158]

3.2.3 European-Level Investment, Coordination, and Strategy

The European Union (EU) has developed a coordinated, international strategic framework to better leverage and develop the waterways. This framework, specifically on the Rhine, emerged from a history of informal and spontaneous collaborations centered on addressing economic and environmental concerns.

The introduction of the European Union's Water Framework Directive (WFD) in 2000 established both a compliance and policy mechanism. The WFD clearly articulates specific deadlines and standards for measures including the establishment of international river basin districts (IRBDs) and required river basin management plans

(RBMP). These RBMPs enable substantial local control within a macro-level EU framework, as well as require frequent reports on a river's ecological health, stakeholder consultation process, and measurements of river use.[159] This multilevel, polycentric structure relies on a blend of broad oversight and local influence and coordination among and between governments, professionals, environmental NGO's, nearby residents, and consumers. The institutional diversity of stakeholders engaged in river basin management, as well as the diffusion of power, has enabled the minimization of competition for key resources and the development of adaptive capacity, or the ability for river management institutions to adjust to complex and rapidly changing circumstances.[160]

The actual process of river basin planning typically involves four key components:

- River system characterization and assessment
- Monitoring
- Environmental goal-setting
- Design and implementation of actions to achieve those objectives

As this cyclical approach requires plan renewal, it facilitates continuous engagement; and flexibility in river management is facilitated by regular renewal of the plan.[161] Additionally, each member state may determine the legislative body tasked with implementing the RBMP. As a function of this significant flexibility in management, various organizations exist on a basin, sub-basin, country, and local level, creating a complex web of overlapping jurisdictions. Austria, for instance, established the Austrian waterway operator in the Federal Waterways Acts to manage the Austrian area of the Danube, including all nine locks that exist within that section of the river. At the same time, Austria's overall waterway strategy is guided by the Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation, and Technology.[162] While it is unclear how much these two entities interact, Austria demonstrates the complexity of river and lock management; the Danube is not only fragmented on a macro and regional level, but also by each country's local management organizations.

The EU, guided by the WFD and other policies, also provides significant funding for many of the projects on these rivers. It should be noted, however, that European funding on a macro-regional level is integrated into national and regional EU programs, meaning that many EU strategy programs do not maintain their own budget as part of a newly implemented 'cohesion' policy. Instead, they draw from the five European structural and investment (ESI) funds, such as the European Regional Development Fund (ERDF).[163] For example, the Danube Transnational Program obtains its allocated budget from the ERDF, Instrument for Pre-Accession Assistance (IPA), and the Neighbourhood, Development and International Cooperation Instrument (NDICI), though all originate from the EU.[164] Additionally, a substantial number of initiatives

(and organizations tasked with implementing and funding them) exist for both rivers. The examples covered below do not constitute an exhaustive list of the many stakeholders and directives that impact this river system, though they are likely the most significant.

The EU provides sizeable contributions through the European Regional Development Fund (ERDF), Instrument for Pre-Accession Assistance II (IPA II), and the European Neighborhood Instrument (ENI). The Danube Transnational Program (DTP) is a principal funding mechanism and a project of the European Territorial Cooperation (better known as Interreg).[165] With a approximately $225 million budget for the 2021-2027 period, it encourages national, regional, and local level cooperation between members.

The DTP finances many projects and complements one of the most important EU-level actions, the Strategy of the European Union for the Danube Region (EUSDR, formerly INTERACT). While EUSDR and DTP roles intersect, the EUSDR differs in the sense that, like other EU macro-strategies, it does not have its own budget and thus is not a funding mechanism. Recently, the 14 Danube member states approved the EUSDR's Danube Region program cooperation plan for 2021 to 2027, which will soon be submitted to the European Commission with final approval expected in June 2022.[166] Out of the program's twelve priority areas, Priority Area 1A (Waterways Mobility), seeks to enhance waterway conditions, boost fleet modernization through EU and state-based funds, improve Fairway Information Services, and refine administrative processes.141 EUSDR projects include PROMINENT, which was funded by Horizon 2020 with the goal of transitioning to more sustainable vessels, incorporating IWT into sustainable supply chains, and certifying and monitoring emissions.[167]

Other projects on the Danube are also funded by CEF Transport. These include lock and port upgrades and the elimination of operational bottlenecks by expanding data exchange and simplifying administrative processes. FAIRway Danube is a CEF project focused on improving navigation through improved information sharing about water levels. This is accomplished by utilizing surveying vessels and investing in water-level gauges.[168]

The Trans-European Transport Network (TEN-T) identifies nine Core Network Corridors as the most important linkages across various transportation modes, as well as 30 priority projects, including the Rhine-Main-Danube waterway axis.[169] Currently, CEF Transport funding allocates almost $4 billion to these projects, although most involve railway development. Approximately $270 million has been allocated to inland waterways specifically.[170]

Funding may also originate from other sources, such as the European Climate, Infrastructure, and Environment Executive Agency (CINEA), which assumed the responsibilities formally undertaken by the Innovation and Networks Executive Agency (INEA) in February 2021. CINEA has a budget of nearly $60 billion for the 2021-2027 period. While these funds are generally spread out across a variety of projects, CINEA manages several programs related to inland waterways, including CEF. One project, FAIRway Works, is the successor to the FAIRway Danube project and is scheduled for 2020-2023. With a budget of some $48 million from the CEF and CINEA, the project will be jointly implemented by Austria and Serbia. It includes upgrades to the Iron Gate II navigational lock, mooring operations, and equipment expansion.[171]

Other notable projects include NAIADES, which focuses on smart water management through the modernization and digitalization of water management systems, and the subsequent NAIADES II (ending in 2020) and III (2021-2027). [172] Projects II and III feature a specific focus on inland waterways, and take a particular interest in increasing freight transport and zero-emissions fleets. As there are numerous EU-level entities involved with inland waterways, jurisdictions often overlap as organizations work toward common goals.

On the land side, European port development focuses on building terminals and upgrading existing infrastructure rather than new construction.[173] Some foreign investment exists at the port level, especially by Chinese companies. Notably, COSCO and CMPort hold shares across Europe but mostly in the coastal port sector.[174]

Cabotage regulations in the EU were revised as of February 2022.[175] Due to the connections between many EU Member States, European cabotage diverges from the traditional definition and can include “transport between two ports in the same country or between two ports of two different countries that are located on a coast or a river.”[176] For instance, on the Rhine the CCNR specifies that vessels with the right to fly either the CCNR or EU flags as Member States may provide documentation and engage in cabotage, defined as ’traffic between two Rhine ports.’[177]

Regarding user fees for navigation, the EU and member states exclude waterborne transportation from taxation, particularly due to related agreements regarding the Rhine and Danube’s management. Since its initial application in 1952, Article 3 of the revised Mannheim Agreement, which provides the legal framework for the Rhine, explicitly exempts diesel used on the Rhine from taxes. It also outlines that “no duty based solely on navigation may be levied on vessels or their cargoes or on rafts navigating on the Rhine or its tributaries.”

Any revisions to funding rules would require the cooperation of non-EU states, such as Switzerland, Serbia, and Croatia.[178] Other rules might require cooperation from non-EU states that do not border the rivers, such as Ukraine and Moldova, because they are within the Danube River Basin and thus are members and contracting parties of the ICPDR, the key implementation tool for the WFD.

However, a 2021 proposal for a Council Directive revising the EU's Energy Tax Directive 2003/96/EC, which structures the EU's rules and rates for taxes on energy products such as fuel, is in progress. If adopted, the legislation would remove the exemption and impose a new minimum tax rate on certain energy products for intra-EU navigation, fishing, and freight transportation. The minimum rate on alternative fuels, such as biofuels, would be zero for ten years to promote their use. In addition, EU member states would be required to take action to eliminate contradictions in agreements, such as the Mannheim Agreement, that would be in conflict with the new measure. The proposal leaves taxes on 'extra-EU waterborne navigation' to the discretion of member states.[179]

3.2.4 Europe Summary

The European river system demonstrates the value of coordination and strategic investment in inland waterway networks. Europe is disadvantaged with a complex governance structure, including more than a dozen countries involved in the Rhine and Danube rivers alone. Each of those states is responsible for its portion of the river, with the EU coordinating and funding investments. These rivers are also highly complex from an infrastructure management perspective, in that dozens of lock-and-dam systems are along the Rhine, Danube, and connecting canals. The waterways require significant dredging for most of their length, and must deal with variable water levels.

These challenges mean that the potential sources of disruption to the system are many. Incidents related to climate change impacting water levels, breakdowns on any of the connecting locks, or traffic disruption due to the war in Ukraine, all have implications for not only national but European level trade and security.

Despite these challenges, they both are vital corridors for trade. The Rhine in particular has been developed in a way that it moves not just bulk goods but also containerized freight. For high-value goods movement on inland waterways to be successful, the system must be reliable and port facilities must have adequate infrastructure to facilitate transloading. Europe does this through a strategy that requires that significant high value goods move on waterways instead of nearby roadways, coordinated investments at the EU level, and an emphasis on operations and maintenance that enable the predictability industry needs.

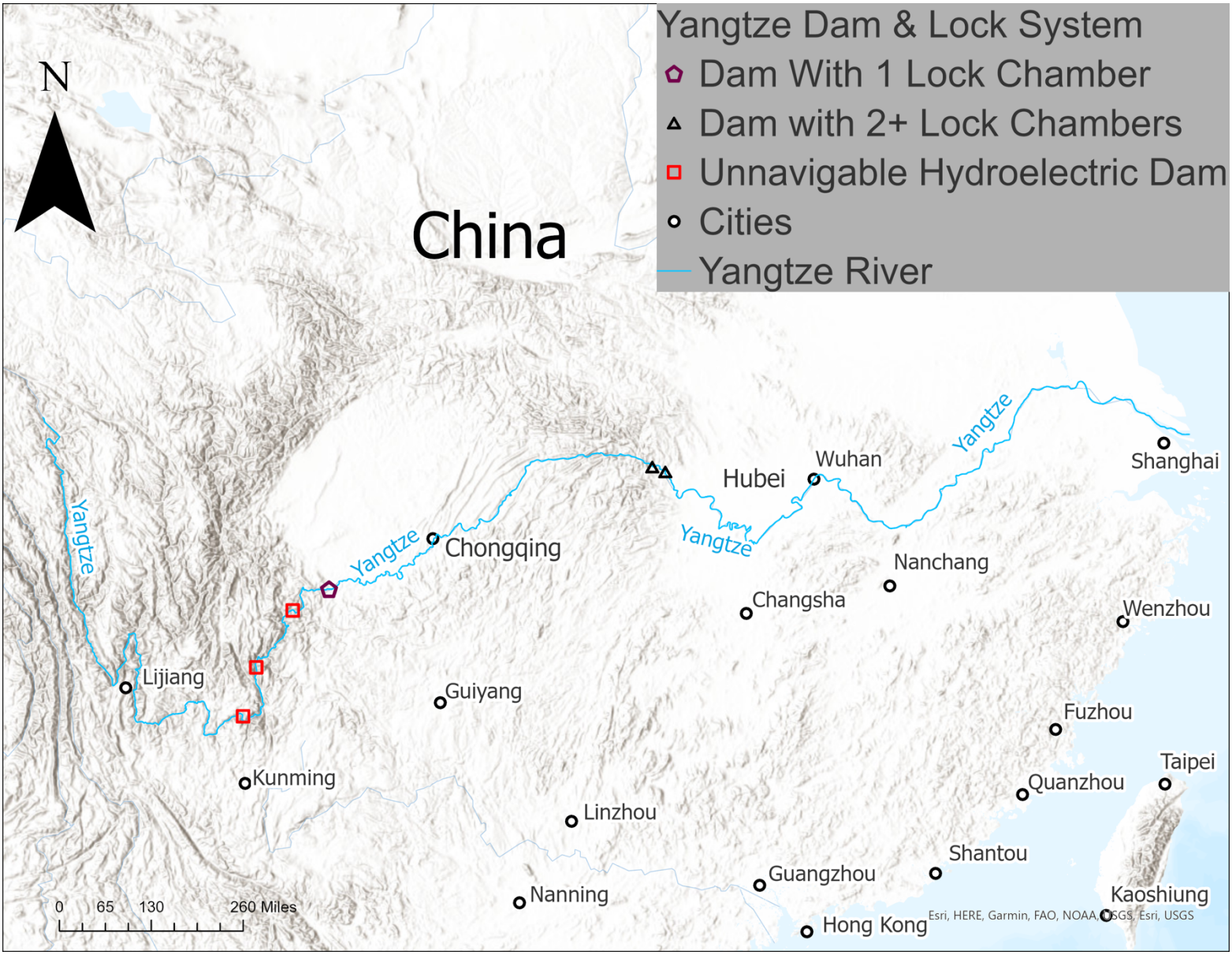
3.3 China and Southeast Asia

There are many rivers on the Asian continent and historically they have been a vital source of water, trade, and regional power. A few of them have significant freight volumes, including the Yangtze, the Mekong, and the Ganges. This section focuses on the Yangtze, the busiest freight river in the world, and one that has been a primary source of low-cost transportation in China's industrial heartland; and the Mekong, a busy freight river for Vietnam and Cambodia with heavy influence, investment, and control from China.

3.3.1 Yangtze River

The Yangtze River, or Chang Jiang, is the longest river in Asia and the third longest in the world, at 3,915 miles in length, of which 1,700 miles are navigable.[180] The river is entirely contained within China, as seen in Figure 9. The Yangtze watershed gathers in more than 3,600 tributaries and extends over 698,265 square miles in the catchment area.[181] The primary navigation channel, which stretches between the cities of Yibin in Sichuan province and Yichang in Hubei province, traverses China's industrial and agricultural heartland, including the city of Chongqing.

Figure 9: Yangtze River System



Sources: United States Army Corps of Engineers, 2022; National Weather Service, 2010; Esri Data and Maps 2021; Google Maps Satellite Images 2022.
Full interactive map here: https://arcg.is/ovvrCW

Among the most integral part of an extensive system of hydropower plants and dams, the Three Gorges Dam was completed in 2003 and is the world's largest hydroelectricity plant.[182] This two-lock hydro-complex has five gates on each lock to lift and lower vessels up to 10,000 tons, increasing the length and capacity of the existing navigable passage between the city of Chongqing and Hubei.[183] The Yangtze River's geographical attributes are conducive to transporting goods between regions, provinces, cities, and industrial zones within China.

Throughout all of China, inland ports have nearly 22,000 inland vessel berths, including 418 ports that can handle vessels of 10,000 deadweight tons (DWT) and above.[184] Most of these berths are concentrated in the downstream sections of the Yangtze River, and are also accessible to large seagoing and coastal vessels.[185]

Freight Flows

The development of inland waterway transport in China, especially along the Yangtze River, is associated with China's growth in manufacturing goods that serve both global and domestic markets. Inland port throughput has increased each year since 1987 and reached more than 4 billion tons nationwide in 2018, with 2.69 billion tons alone coming from the Yangtze.[186]

As China's GDP is increasing, so too is domestic consumption. From 1980 to 2018, China's national GDP expanded 25-fold, and its share of global GDP rose to account for about 18.7 percent in 2018.[187] China's economic development has moved from the stage of high-speed growth to that of high-quality development.[188] Many of China's smaller cities are becoming hubs for fast-growing industries such as electronics, pharmaceuticals, and machinery. Economic activity, including mining, manufacturing, and energy production, is widely distributed along the Yangtze River.[189]

Most of the cargo handled at Chinese inland ports is domestic in nature, with only about ten percent of inland cargo being shipped internationally.[190] Both the investments in inland waterway transport and the volumes handled at inland ports have steadily increased from 1986 to 2018. Since 1986, the total investment in inland waterway transport has accumulated over $92 billion, while the investment in inland water channels topped $68 billion in 2018.[191] The objectives of the investments are to provide more efficient and productive river-based transport relative to other modes.[192] The improved navigation conditions include stable channels, increased draft allowances, the ability to accommodate a higher class of vessels, all of these resulting in reduced unit costs, faster transit times, and increased ship-lock capacity.

The density of industrial and population clusters along the Yangtze River enables inland waterways to serve as an inexpensive yet strategic transportation mode. One-third of the country's entire population is concentrated within the river basin.[193] China's large population creates a demand for goods that is met in part by the inland waterway system.[194]

Business clusters and large enterprises, which typically include energy-intensive industries such as steel, petrochemical, and thermal power, were also foundational to the development of bulk cargo transportation along the river.[195] The decentralization of

Chinese port governance has also contributed to keeping the cost of inland waterway transport relatively inexpensive. Further, competition between ports has allowed the cost of inland waterway transport to remain competitive.

Governance and Administration

The Chinese Ministry of Transport (MOT) is responsible for policy development and regulation of the Yangtze. Regulation, enforcement, and infrastructure delivery are also carried out by its subagency, the Yangtze River Administration of Navigational Affairs (CJHY).[196] As a subordinate to the CJHY, the Yangtze Waterway Bureau is also responsible for the construction and maintenance of the trunk waterways of the Yangtze River.[197] The Comprehensive Plan of Water Resources in the Yangtze River Basin (2010), and the Comprehensive Plan for Yangtze River Basin (2012), provide the regulatory context for the river's management.[198]

According to Article 4 of the Maritime Code of China, foreign-flagged vessels are not allowed to conduct domestic transport or transshipments in Chinese waters without obtaining approval from the MOT.[199] The inland waterway sector allows an exception in which non-Chinese flagged or international freight-forwarding vessels can operate on particular routes between Shanghai and other river ports if they are owned by Chinese-funded companies or joint ventures registered in China.[200] However, interpretations of this exception vary between local authorities, and foreign-flagged vessels are advised to obtain the MOT's approval prior to operating on the river.[201]

The State Council of China initiated a major program to strengthen the Yangtze River Economic Super-zone in 2014.[202] The program was designed to increase shipping capacity and intermodal transportation on the river through the expansion of road and railways, construction of logistics centers, and other infrastructural improvements.[203]

The "Made in China 2025" policy, released in 2015 as part of the government's ten-year plan, is foundational to China's goal of becoming the top producer and manufacturer of global high-tech manufacturing, end-to-end processes, and end-products globally and domestically.[204] With a focus on catering to domestic logistics, inland waterways play a critical role in the rollout of this plan.

From the early 1980s to the early 2000s, governance reforms, characterized by decentralization and market orientation, shaped the inland port structure along the Yangtze River.[205] In these reforms, local governments, rather than the national government, became the primary entities responsible for port infrastructure. These reforms also significantly boosted the development of the inland ports, leading to a major increase in terminal construction and a high level of competition among the river's ports.[206] Local governments are incentivized to make investments that respond to

local needs as well as those of various port stakeholders.[207] The result is an excess of terminals, with more than 3,900 cargo berths currently on the mainstream waterway of the Yangtze River (or more than two berths per mile of river). For the Yangtze, specifically, the growing number of new ports has led to an underutilization of port resources and an increase in pollution from port-related industries.[208]

The main source of port investments (more than 50 percent) is from the local port enterprises.[209] The financing avenues include national and local budgetary funds, MOT's dedicated funds, loans by domestic banks, foreign capital, local self-raised funds via stock issuance, and funds from business enterprises and other institutions. The combination of navigation development and power generation (e.g., power generation for navigation) are promoted as financing tools for multichannel fundraising opportunities on the basis of shared investment, risks, and profit. In such projects, navigation locks and facilities were built alongside micropower generation facilities.[210]

In China, private individuals from foreign countries as well as private entities such as multinational enterprises are encouraged to invest in the "special economic zones" in which they are eligible to receive preferential tax and tariff treatment.[211] The Yangtze River Delta, located at the mouth of the Yangtze River, is one of the most important economic zones in China. It is home to many prominent businesses and enterprises and houses a national state-owned port enterprise, the Shanghai International Port Group (SIPG). The SIPG has attempted to facilitate coordination among and between the largely decentralized ports, and has funded several critical port development projects among the 15 national inland ports in the Yangtze River Basin.[212] The rationale to realign local control to national interest enables the management of ports to become more responsive to the trading interests of the central government.[213]

Chongqing is a prime example of high utilization of inland waterways to boost freight connectivity. Chongqing — a city of 31 million inhabitants located about 1,367 miles from Shanghai, at the upper reaches of the navigable portion of the Yangtze — is the first and among the most strategic inland exchange shipping centers in western China. The Yangtze crosses the city; the Jialingjiang, a tributary of the Yangtze, meets the Yangtze in Chongqing; and the city has other small rivers passing through it. Chongqing province has about 900 miles of navigable waterways of which approximately 423 miles are in the Yangtze River.[214] Total cargo throughput at Chongqing ports reached 204 million tons and 1.2 million twenty-foot equivalent units (TEUs) in 2018.[215]

The city of Chongqing is not only connected to the eastern seaboard via the Yangtze and Europe via China-Europe freight trains as shown in Figure 10, but it is also connected to Southeast Asia via Qinzhou, in south China's Guangxi Zhang Autonomous Region. To the north, trains carry goods between the city, Russia, and beyond.[216] The inland

waterway system is connected to other transportation networks so that products from European countries can reach China's western inland via existing China-Europe freight trains.[217]

Figure 10: Chongqing-Duisburg Trans-Eurasia Railroad

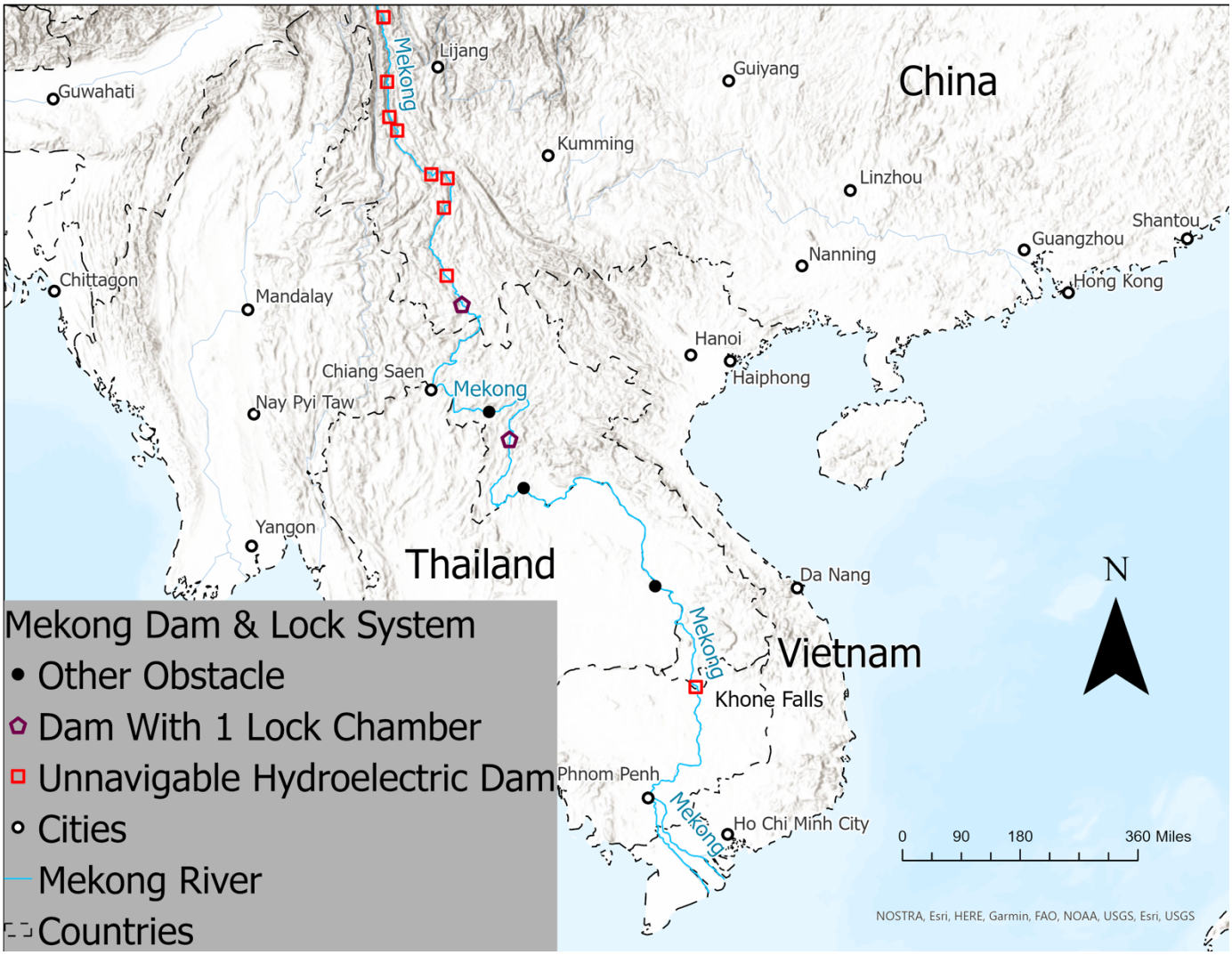
Source: China Daily, 2013

The construction of hydropower plants along dams and ship locks is another priority for China in maximizing inland waterway system use and fostering regional development. Yet, hydropower plants do pose significant environmental challenges and officials have had to address concerns over the displacement of local communities.[218] Increasingly rapid urbanization, climate change, and damming projects have raised concerns about water pollution, ecosystem health, and water availability. This is especially concerning as water from the river provides around a third of the country's water consumption.[219]

3.3.2 Mekong River

The Mekong River in East Asia extends from the Tibetan Plateau to the South China Sea. The river is approximately 3,000 miles in mainstream length and passes through six countries: China, Myanmar, Thailand, Laos, Cambodia, and Vietnam. The river is heavily used as a freight corridor in the lower 200 miles by Vietnam and Cambodia. While this portion of the river is affected seasonally by a "flood pulse" driven by snowmelt runoff and heavy monsoons, the Tonle Sap River links the Mekong to Tonle Sap Lake in Cambodia, which serves as a detention reservoir during the flood pulse season for the lower stretches of the river. Climate change is contributing to changes in the river flow and flood dynamics.[220]

Figure 11: Mekong River System



Sources: United States Army Corps of Engineers, 2022; National Weather Service, 2010; Esri Data and Maps 2021; Google Maps Satellite Images 2022.
Full interactive map here: https://arcg.is/ovvrCW

In 2017, merchandise exports and imports on the Mekong River totaled $540 billion, up from $500 billion in 2016.[221] Cambodia and Vietnam, the two nations that share the Mekong River Delta, have been utilizing the Mekong River as their commercial waterway, reaching 128 million tons of transported goods in 2018.[222]

Although the Mekong is one of the six river waterways globally that have annual volumes of more than 100 million tons, the traffic flow from its upper to lower basin is fragmented. [223] The majority of traffic volume in the Mekong River is in the lower system, in the Mekong River Delta located at the mouth of the river. The Khone (or Khone Phapheng Falls) cut the river in half from a navigability perspective, making the Mekong impassable for vessels.

Compared to the lower system, traffic volume along the upper basin is not as robust. In Laos, smaller vessels operate along the Mekong to bring agricultural products and construction materials to and from areas only accessible by river. Reasons for this underutilization of such an important waterway include geography and weather disruptions in the drought and flood seasons. Underdeveloped infrastructure and management, coupled with lack of investment, also pose development obstacles for the Mekong River. As a result, the Mekong has limited traffic for much of its length, and investment is almost all focused on hydropower, not navigation. There are two navigable dams, one in Laos and one in China near the Laotian border, that have locks. However, they serve only internal Laos-China shipments.

Governance and Administration

The Mekong River Commission (MRC), established in 1995, is an intergovernmental organization for regional dialogue and cooperation for water diplomacy as well as water resources management for the sustainable development of the region. The MRC is governed by four countries in the Lower Mekong Basin: Cambodia, Laos, Thailand, and Vietnam. China and Myanmar, in the Upper Mekong Basin, have remained as MRC's Dialogue Partners since 1996. The MRC is responsible for establishing the goals, objectives, and underlying principles by which the four Member Countries intend to cooperate and oversee the future development of the river. [224]

As a dialogue partner, China cooperates with the MRC in terms of exchanging technical expertise and information in a number of areas such as flood prevention, water and environmental management, and hydropower.[225] The MRC anticipates a variety of funding sources, including international and regional grants, supplemented by national public budgets. In addition, the MRC is exploring a regional Mekong Fund to attract a wide source of funding for transboundary issues such as social and environmental investments and water-related disaster recovery.[226]

In China, Yunnan Province, the only province the river runs through, is responsible for policymaking at the provincial level along the Mekong River.[227] Yunnan administration oversees eight hydropower dams on the upper stretches of the River in the southwestern part of the Province.[228] In October 2020, China agreed to provide the MRC with year-round hydrological data from two stations in Yunnan Province, contributing to better river monitoring and flood and drought forecasting in the Mekong countries.[229]

Article 19 of the Greater Mekong Subregion Cross-Border Transport Facilitation Agreement (CBTA) establishes guidelines for traffic rights and indicates that cabotage may only be conducted with special authorization from a given country.[230] In general, however, cabotage is prohibited and any operators engaging in unauthorized cabotage face a cancellation of their permit and exclusion from the CBTA.[231]

China's Participation in the Mekong River's Activities and Geopolitics

Although China is not a member of the MRC, it actively participates and joins the MRC in promoting sustainable growth through the Lancang-Mekong Cooperation. China's use of the Mekong waterway is largely focused on building hydroelectric dams.[232] Chinese convoys regularly transport passengers and goods between the southern ports of the country and the port of Chiang Saen in Thailand.[233] The Chiang Saen Port, located in the remote northern province of Chiang Rai, was built to improve Thailand's tourism, trade, and investment network.[234] The port's location is a connection point for trade with Yunnan and other southern provinces of China, Myanmar, and Laos.[235]

While still very small compared to the lower section of the Mekong, the Chiang Saen commercial port has experienced increasing trade volume in the years since it began its operation in 2011, likely due to the ASEAN-China Free Trade Agreement that came into effect as of 2010.[236] Chinese and Lao vessels are principal users of the Port.[237] Chiang Saen is also used for the transport of refined petroleum products from Bangkok thanks to an infrastructure that supports the low-cost transport of bulk and liquid bulk cargo.[238] The operation of the Chiang Saen port provides the Chinese government with a continuous supply of oil products and diesel from Thailand to China.[239]

Thailand, Laos, Vietnam, and Myanmar only use small vessels for local transport.[240] Aside from China, the other countries bordering the Mekong River have limited use of the waterway. Vietnam, for example, benefits from its strategic position along the lower basin of the Mekong for trade and growth but lacks the modern infrastructure to boost trade. As a result, the Lancang-Mekong Cooperation (LMC), established in 2016, presents an opportunity for technical exchange, capacity building, drought and flood management, data sharing, and joint research among other cooperative initiatives.[241]

The LMC is also seen as a mechanism to strengthen regional dialogue and cooperation between the MRC and Myanmar and China. The five-year Memorandum of Understanding (MOU), which was signed in December 2019, promotes the sustainable social and economic development of the Mekong countries in a way that goes beyond China's role as a partner to the MRC.[242] In the MOU, the Lancang-Mekong Cooperation is defined as a new regional-level effort which promotes sustainable partnerships among the six Mekong riparian countries and advances MRC's standing in China's Belt and Road Initiative through consultation and collaboration.[243] The MOU also facilitates MRC cooperation with China and Myanmar through the Lancang Mekong Water Resources Cooperation Center (LMC Water Center), established in 2017.

Investments and loans serve as important financing tools for China to expand its involvement in the waterway activities of the Lower Mekong Basin, especially in the energy sector. From 2005 to 2021, China provided more than $99 billion worth of investment and construction projects to the five lower Mekong countries (Table 3).[244] Nearly one-third of the total financial aid went to Vietnam, mostly for the energy sector. The majority of investments in Laos are for the construction of several dozen hydroelectric dams along the Mekong and its tributaries.[245] These financing tools provide China with a strong bargaining position relative to the other five MRC countries, making them vulnerable to decisions made externally from Beijing.[246]

Table 3: Chinese Investments and Construction Projects in Lower Mekong Countries (2005-2021)

Country	Value (U.S. $ billions)
Vietnam	30.15
Laos	29.81
Cambodia	18.22
Thailand	11.45
Myanmar	9.88
Total	**99.51**

Source: Compiled from "The China Global Investment Tracker," American Enterprise Institute, 2021

When categorized by sectors, $50.23 billion of the investment went to the energy sector, including the construction of hydroelectric dams. The transport sector received $23.83 billion, mostly for railway construction and highway development.[247] Plans for the construction of as many as eleven hydropower mainstream dams in Laos and Cambodia pose threats to biodiversity, fisheries, and human livelihoods.[248] These dams can also

potentially interrupt the navigability of the Mekong and other rivers, as they can alter the natural flow of the river and divert the Mekong's existing water flow which supplements the flow of other tributaries.

Along with the environmental concerns, other countries in the lower basin also express concerns that these new dam constructions would deplete and restrict the water's flow, especially in the drought and flood seasons. Although the projects promise to control water flow more effectively, China's development of dams where the Mekong River flows into the lower basin of the river makes the other countries dependent on China's decisions regarding closing and opening the gate in the upper basin.

In its role as a technical exchange partner, China was not obligated to consult the other Mekong countries in the MRC on dam construction plans.[249] China's stated goals of reducing poverty and attracting investments to the landlocked provinces of Yunnan can only be achieved by developing infrastructure along the shipping routes between Yunnan and northeastern Thailand, particularly through building dams.[250] Plans by China to construct hydroelectric dams and undertake other activities in Laos in the lower Mekong basin do not commit to a delimited timeframe as set by the rules of the MRC.[251]

3.3.3 China Summary

China's involvement in the Yangtze and Mekong rivers has led to two drastically different outcomes in terms of inland waterway freight movements. Both rivers however contribute to China's ability to exert global influence. The Yangtze River is the busiest inland waterway corridor in the world. It has 630 miles of uninterrupted channel, with several connecting rivers and canals, that connect many of its large industrial cities to the eastern coast and ports for imports and exports. A wide range of goods, low and high value, are moved to hundreds of port facilities lining its banks. China's investments in upstream dams include lock systems to enable goods movement along with hydropower. Large freight volumes are moved despite a lack of coordination at the national level, and recent developments to connect the inland system with foreign and domestic land-based freight networks imply continued growth on the system.

The Mekong River is heavily used over the first 200 miles in Vietnam and Cambodia, but beyond that it is a river primarily used for hydroelectric power. The upper stretches of the river are cut off from the lower at Khone Falls, a large waterfall with no planned developments for a bypass canal. China's investments in its own portion of the Mekong River and its foreign investments in dams in Laos indicate that navigation is not a priority as most of these hydroelectric facilities do not include lock or ship lifts. In fact, Chinese investment in hydropower might be viewed as an impediment to navigation on the lower stretches of the river, as other countries have complained about a lack of

control over water flow during times of drought. While the Mekong has geopolitical implications over water resources, its role as a future major freight corridor appears to be limited.

4.0 International Inland Waterways Themes

Each inland waterway case represents a unique set of political, economic, geographic, and social circumstances. However, common themes emerge about governance, investment priorities, and environmental pressures, that may offer lessons to guide inland waterway investment and policymaking in the U.S.

Governance

Each inland waterway system involves a complex set of actors with sometimes competing interests. Governance includes the public and private sector entities that manage the waterway use, prioritize investments, and oversee its development. Even when a river is entirely contained within a single nation, as is the case with China and the Yangtze River, governance still must balance national and regional or local priorities.

Governance is more complex when it includes negotiating agreements between countries that share the river system. In the case of the Paraná-Paraguay and the Amazon in South America, as well as the Mekong in Asia, a dominant player like Brazil or China will often dictate the terms of engagement. In China's relationship with the nations of the Lower Mekong Basin, both investment decisions and control of the water flow from key dams affect usage of the river within countries downstream.

The EU's management of the Rhine-Danube provides several positive lessons regarding governance. Despite multiple countries with jurisdiction over the rivers, a highly structured set of agreements and associations provides a forum for negotiation at the system-wide level while much of the responsibility for funding and planning remains within the nations through which the rivers pass. This offers a balance between more coordinated planning and localized implementation. It also reflects the responsibilities that national governments have to fund waterway improvements.

Also, while the EU Water Framework Directive (WFD) enables broad oversight and enforcement, regional and local stakeholders have the flexibility to adjust according to their specific needs and goals. Most significant to the WFD may be the continuous emphasis on sustained coordination: this directive allows stakeholders to establish partnerships and set the foundation for formal and binding agreements in the future. The use of funds to support the streamlining of administrative processes highlights the importance of institutional measures and reforms that facilitate inland waterway projects.

However, plans and coordinating bodies do not necessarily translate into development if countries do not adhere to them. For example, the establishment of inter-agency and international cooperative bodies in South America appears to have added layers of processes without alignment of priorities or funding for implementation.

The case studies also reveal the opportunities afforded by decentralized decision-making in addition to providing some cautionary tales about the same. In the Yangtze case study, decentralized port development stimulated locally-responsive use of the waterways and contributed to rapid economic growth. However, it also appears to have resulted in an overdevelopment of port infrastructure and a lack of coordination on the development of regionally and nationally integrated land side transport networks.

Investment Priorities

The case studies illustrate the importance of identifying the comparative advantages of a particular waterway and the need to prioritize investments accordingly. In the case of the Mekong, investment priorities are largely geared toward China's desire to enhance its hydroelectric capacity, not for navigation. China's disproportionate influence on the development of the Mekong makes coordination more difficult among the nations of the lower basin. This in turn has translated into underinvestment in the system.

In contrast, the Yangtze River provided China with an opportunity to take advantage of the density of both its population and its industrial base to develop the world's busiest inland waterway trade corridor. It currently meets the needs of a growing domestic market for high-end consumer goods but also connects to coastal ports that are part of the global trading network. Recent investments indicate a trend toward further leveraging the Yangtze as a trade corridor for transportation within and beyond China.

In South America, natural navigability on the Amazon means that investments in dam and lock systems are not needed. Its growing traffic is mostly due to agricultural and industrial development within the region, despite significant environmental concerns. On the other hand, the HPP needs significant investment to maintain channel depth and operate locks on the Paraná River, but this has not been a priority for HPP countries. This is despite the fact that landlocked Bolivia and Paraguay depend upon the river system for access to deep water ports and export markets. Also, the HPP already cuts through agricultural hubs, and if the government or private entities invested in necessary port infrastructure, the river could accommodate significant bulk agricultural products.

In Europe, the Rhine is fully connected to coastal-based systems and passes through some major population centers. The priority here is enhancing capacity to allow growth in, among other things, container-based trade. Investments are needed for lock modernization, operation, and maintenance of the shipping channel at a level that is attractive to shippers of high-value goods.

In terms of FDI, ports and port facilities are the path to foreign investment and influence rather than the waterways themselves. Private companies in all of the three regions benefit from the opportunity to build special-purpose facilities that meet the needs of a particular commodity or industrial sector. Concessions and public-private partnerships also facilitate foreign influence when foreign ownership is precluded by governmental statute, as is the case in Brazil.

Managing Waterway Risks

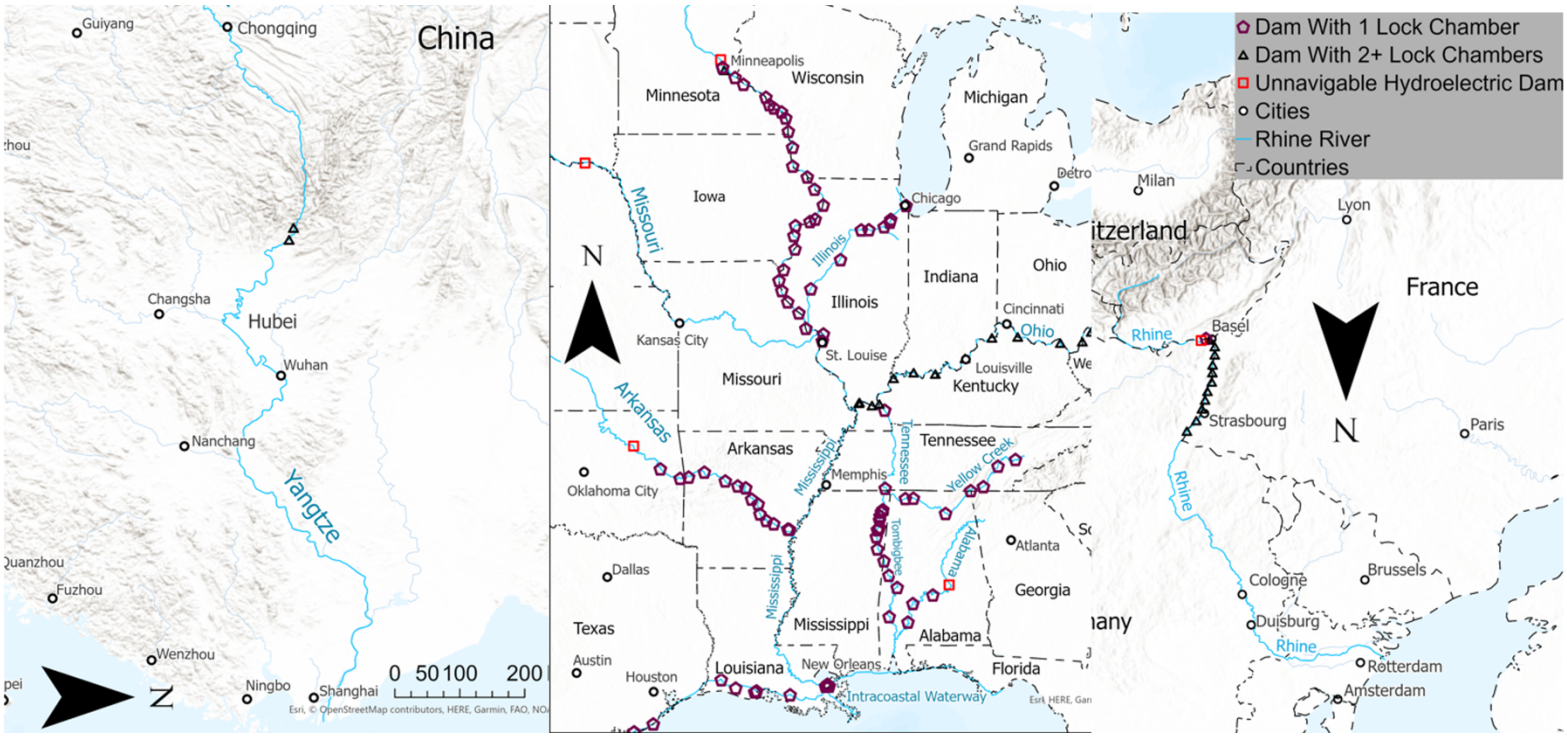
Shipments on waterways can be a low-cost and environmentally sensitive way to move goods. But their efficiency can easily be undermined by unreliability. Lock failures and low waters can cause hours, days, and sometimes weeks in delays for shipments. Waterways have no detours or alternative routes, and transferring to another mode is a highly costly exercise. This research shows that when governments make investments that signal high reliability to shippers, they use the system. And when waterway systems do not enable efficient and dependable navigation, shippers establish alternative supply chains.

The use of container-on-barge services, or any other high-value goods movement, is a signal that the industry trusts in the system. However, for inland waterways to be competitive with containerized goods, the systems need close integration with coastal, blue-water ports (as with the Rhine but not the Danube, the Yangtze but not the Mekong) and a policy environment that is willing to offset the clear time, and in some cases cost, advantages that road and rail networks have over river-based systems.

The U.S. inland waterway system has very limited container-on-barge operations for several reasons. Historical unreliability and underinvestment have likely deterred some private sector investment in such services. Parallel railroad services offer low cost and fast service compared to the waterways. Also, the distances between ports and the major population centers are not conducive to moving high value, time sensitive goods. Figure 12 compares the distances on the Mississippi to the Yangtze and Rhine, each to scale and oriented to match the directional flow of the Mississippi. Large population centers and economic activity are on the lower stretches of the Yantze and Rhine, whereas on

the Mississippi there is much smaller population between Baton Rouge and Memphis. Also, because the Mississippi is significantly more meandering, the distance between New Orleans and Memphis, is more than 640 miles via the river.

Figure 12: Scale Comparisons of Select Inland Waterway Systems



Sources: United States Army Corps of Engineers, 2022; National Weather Service, 2010; Esri Data and Maps 2021; Google Maps Satellite Images 2022.
Full interactive map here: https://arcg.is/ovvrCW

The physical limitations of the U.S. inland waterway system will continue to be a barrier for high value goods compared to other countries. The publicly-supported container-on-barge services through the America's Marine Highway Program can work, but their broader application is unlikely. Providing for higher reliability and better management of risks will help current and future shippers, and might provide future market opportunities.

Finally, all of the cases demonstrate the need to address environmental risks related to inland waterway development for whatever purpose. An emphasis on the development of hydroelectric power along a river, including the construction of dams, may result in flooding that eliminates habitats and require the displacement of entire communities.

River use for the purposes of navigation and trade are also subject to environmental changes. Variable water levels impact system capacity; and population growth in river basins may increase the demand for water to be diverted for other purposes, including as drinking water. Environmental risks are highest in systems in South America as well as the Mekong.

Effective governance, investment strategies, and risk management all serve to enhance system reliability and reduce vulnerability. An ability to ensure continuity of operations allows the system to contribute to economic growth, and should it be needed, for purposes of defense. Poorly managed systems therefore pose a risk to not only economic stability but national and regional security as well.

5.0 Conclusions for U.S. Competitiveness

While the social, political, and economic forces at play in the other regions constitute a unique set of circumstances, there are valuable findings about practices in other regions that will inform U.S. policymakers, managers of the infrastructure, and the users of the system.

First, the United States benefits from having the inland waterways system contained within its borders and governance centralized with the federal government. Collaboration and coordination between countries that share a river system can be complex and challenging. Europe's rivers are well maintained and highly used despite disaggregated governance through leadership at the EU level. The USACE, in collaboration with Congress, manages the waterways and prioritizes investments. Leveraging the centralized governance to improve the inland system is much easier than coordinating across countries.

Second, the United States can benefit from more strategic, multimodal freight planning with inland waterways as a key part of that strategy. Europe's ability to move significant high-value cargo on the Rhine River is the result of a targeted policy strategy where that was the end goal. The region coordinated investments to improve operational reliability and connections to other modes, and the traffic followed. While it might not make economic rationale for significant container-on-barge operations in the United States or expanded subsidies to support it, such outcomes will not materialize unless there is an intentional, coordinated, and fully executed strategy.

Third, the United States needs to carefully watch the development of other nations' freight waterway corridors, particularly China, with an eye toward economic competitiveness and national security. While freight traffic is relatively low, possible development on the Amazon and Paraná-Paraguay rivers represent significant threats to the cost-competitiveness of American exporters. State-owned Chinese companies are investing in facilities along those rivers, but environmental backlash and lack of coordination can limit growth. China's investments in intermodal facilities on the Yangtze could further enhance its use, particularly connecting to other Chinese cities and to railways that lead to Europe. China's involvement in the Mekong does not appear to prioritize freight shipments, but has clear geopolitical implications. Europe's already-developed systems are not a threat, but can be a model for prioritizing reliability and connectiveness on the rivers.

Finally, the increased investment levels of the IIJA offer an opportunity to greatly enhance the reliability and usefulness of the inland waterway system. Now is the time to clear the backlog of projects that are desperately needed to bring some facilities into modern practice. That investment, coupled with improved operational practices and a sound asset management plan, will be a significant boon to existing users. Building on recent efforts to make the system more reliable and dependable for shippers, coupled with inland waterways being a key part of a national freight strategy, further private sector investment and traffic will follow. Strategic investment in domestic waterways will go a long way to securing low-cost options for American exporters and shippers.

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