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Assessing Maritime Infrastructure along the Mississippi: Chokepoints and Implications for Food Security

November 2021 – June 2023

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October 16, 2023

FINAL RESEARCH REPORT
Prepared for:
Maritime Transportation Research and Education Center

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ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Transportation under Grant Award Number 69A3551747130. The work was conducted through the Maritime Transportation Research and Education Center at the University of Arkansas.

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1. PROJECT DESCRIPTION

The Mississippi River is a major part of the MTS and has been referred to as 'America's inland hydro highway'. It is a critical food security corridor functioning as a major trading thoroughfare for US goods and commodities to and from the rest of the world. The complex river system is considered one of humanity's greatest civil engineering feats. However, the strain on the river system is only becoming more acute due to aging infrastructure and the impacts of climate change. Up and down the Mississippi River, new pressures are being put on the river, impacting the environment, wildlife, and cities and towns along the riverbanks. Of particular interest is the impact of these pressures on the creation of chokeholds and vulnerabilities to the food and agriculture supply chains. These supply chains are inherently complex due to their interdependency with critical infrastructure systems including maritime and multimodal transportation with the largest risk to agricultural trade resulting from age and inadequate or inappropriate infrastructure. It is imperative to close the infrastructure gap, which is not just a function of more construction; new developments must be smart and able to withstand increasingly hostile weather and elements of climate change as they age. Consolidating the evidence around the importance of chokepoints on the Mississippi River to food security and enhancing understanding of the nature of hazards and vulnerabilities are key steps in converting chokepoint analysis into policy and strategic action.

The pressure and strain on the water transport infrastructure along the Mississippi river is a serious and urgent issue that requires attention and action from policymakers, stakeholders, and researchers. The purpose of this project is to evaluate the benefits and climate vulnerabilities of the Maritime Transportation system, focusing on port infrastructure, agricultural trade, and resiliency. The Port of New Orleans is used as the study site.

METHODOLOGICAL APPROACH

The Mississippi River Delta is the broad study area for this project. It is considered home to more than two million people. The location of the delta at the mouth of the Mississippi River enables the region to be a cultural gateway into the United States, influencing the mix of nationalities which have settled in region. Selected regions along the Delta will be used for the analysis. The problem to be addressed by this research is understanding the transportation related chokeholds and climate related vulnerabilities in the region and the implications agricultural trade and household food security. Below are the two key research questions that will be addressed:

1. What are the benefits and critical elements of the US maritime infrastructure, particularly along the Mississippi River Delta?
2. What are the major chokepoints and climate related vulnerabilities that impact the MS Delta's maritime infrastructure and overall impacts on food security?
3. What is the status of agricultural trade at Port NOLA and how is the port impacted by considerations such as aging and climate change?

Table 1 is the logic model showing the current situation, activities/tasks to be conducted, expected results and products, as well as expected knowledge, action and impact outcomes to achieve research objectives.

Table 1: Logic Model Showing Tasks and methods used to achieve research objectives.

SITUATION	ACTIVITIES	PRODUCTS/ RESULTS	OUTCOMES Knowledge	OUTCOMES Actions	OUTCOMES Impacts
Inadequate knowledge of the benefits & critical elements of the US maritime infrastructure	Assessment of the economic value of the maritime transportation	GIS maps of maritime transportation infrastructure along the MS River Delta	Analysis on chokeholds, climate change and smart infrastructure	Information and analyses that can used by decision makers in designing smart & sustainable maritime infrastructure	An increased understanding that an efficient transport network lowers production costs and enhances productivity and profits for all
Inadequate understanding of maritime transportation related chokeholds and climate related vulnerabilities on the MS River Delta	Literature review on physical and policy chokepoint identification and analysis	Database and maps on physical and policy chokepoints along the MS River Delta	Increased student, and public awareness of the i) elements & value of maritime transportation; ii) chokepoints within maritime infrastructure; iii) impacts of these chokepoints; and iv) connections between maritime transport and food security	Research community address key knowledge gaps in the fields of food security, maritime transport networks, disaster resilience, infrastructure development & governance, risk assessment and climate science	Improved engagement of stakeholders in climate change, disaster response and transportation planning
Lack of knowledge of impact of and the implications for farmers, the agricultural trade and household food security	Interviews with the Corp of Engineers & key stakeholders to identify chokepoints and the impact of climate change and initiatives for a more sustainable system	Collaborative partnerships with key stakeholders	Increased research capacity and computing skills of faculty and students in CSET		Greater research capacity of CSET's students & faculty
Opportunity to increase student, CSET and public's knowledge about intersection between maritime transportation planning, climate change, disaster management and food security	Creation of GIS maps to identify key marine infrastructure, chokepoints and land use conflicts along the MS River Delta	Open dialogue (workshop/seminar presentation) on the benefits of strengthening US maritime infrastructure			A more climate conscious society
	Article developed and Seminar hosted to disseminate information collected	Journal publication on maritime transportation climate change and food security			Graduates better prepared to work in multi-disciplinary fields

ASSUMPTIONS: Appropriate SFS will lead to more sustainable land use management; Resources are adequate for planned activities; Data gathering is efficient and effective; Research results can be used effectively in teaching and outreach; stakeholders are interested in research findings

EXTERNAL FACTORS: Internal and external partners are interested in, have the resources and invest; General public, NGOs, governmental and other agencies make use of the data and information; the time needed for collaborations is adequate; stakeholders responsive and provide needed inputs.

2. RESULTS/FINDINGS

US Maritime System

The US Maritime Transportation System (MTS), responsible for the movement of passengers and freight over water, controls the majority of the United States' global overseas trade and is a vital backbone of international trade (Wendler-Bosco and Nicholson, 2020). The growth of international trade, the rise of new markets, and the development of multimodal supply chains have significantly reshaped the maritime transportation industry and its infrastructure. As the world's leading maritime and trading nation, the United States relies on an efficient and effective MTS to maintain its role as a global power. The MTS provides American businesses with competitive access to suppliers and markets in an increasingly global economy. Within the United States, the MTS provides a cost-effective means for moving major bulk commodities, such as grain, coal, and petroleum. It is a key element of state and local government economic development and job-creation efforts and the source of profits for private companies. With its vast resources and access, the MTS is an essential element in maintaining economic competitiveness and national security.

Maritime transportation is a distinctive transportation mode with characteristics that are different from other modes of transportation. According to the US Department of Transportation's Maritime Administration, America's MTS is expansive. Its major components include ocean and coastal routes, inland waterways, ports, and ships which all play a vital part in the global supply chain and freight transportation system. According to the 2018 MTS Report to Congress (USDOT, 2020), the MTS includes waterways, ports, and land-side connections, moving people and goods to and from the water. Specifically, the system consists of:

- more than 1,000 harbor channels
- 25,000 miles of navigable channels
- 250 locks
- 3,700 marine terminals
- 361 ports
- 174,000 miles of rail connecting all 48 contiguous States, Canada, and Mexico,
- 45,000 miles of interstate highway & 115,000 miles of supporting roadway
- 1,400 designated intermodal connections.
- 460,000 miles of pipelines

The MTS also contains shipyards and repair facilities crucial to maritime activity. The U.S. Department of Transportation's Bureau of Transportation Statistics reveals that the total value of marine freight has increased significantly every decade, with ferry transport experiencing rapid growth, particularly in response to land-transport congestion and commercial fishing (USDOT, 2023). Trade increases also increase demands on the MTS and must be balanced with environmental values to ensure that freight and people move efficiently to, from and on the waterfronts. According to a January 2021 report from the Maritime Administration, approximately 99% of overseas trade enters or leaves the U.S. by ship with this waterborne cargo and associated activity adding over $500 billion dollars to the US' GDP, generating over $200 billion in annual port sector federal/state/local taxes and sustaining over 10 million jobs (USDOT, 2023).

The MTS supports $5.4 trillion of economic activity each year and accounts for the employment of more than 31 million Americans according to the USDOT and Maritime Department (2020). The MTS is key to national and economic security; 99% of U.S. international trade by volume moves through the nation's ports and the industry contributed 18% of GDP in 2020 (USDOT, 2023). In addition to freight, the MTS supports passenger travel by ferries and cruise ships, as well as commercial and recreational fishing, and recreational boating. The MTS is also essential to U.S. strategic requirements. Nearly 90 percent of the military's supplies and equipment move overseas via the MTS on military sealift vessels or on U.S.-owned, U.S.-flagged and U.S.-crewed commercial sealift (United States Navy (n.d.). The MTS can support contingency functions as well as humanitarian assistance and disaster relief efforts all of which provides a key strategic advantage for the United States.

Easa et al. (2006) describes the main physical components of the marine transportation system (Figure 1) to include (1) navigable waters, (2) vessels (publicly and privately owned), (3) ports (harbor and land-side facilities), (4) intermodal connections (highway and railway), (5) shipyards, and (6) repair facilities. They contend that several important functions are necessary for this physical infrastructure, including: (a) operation, management, and maintenance, (b) safety, security, and the environment, (c) navigation and communication, and (d) education and training.

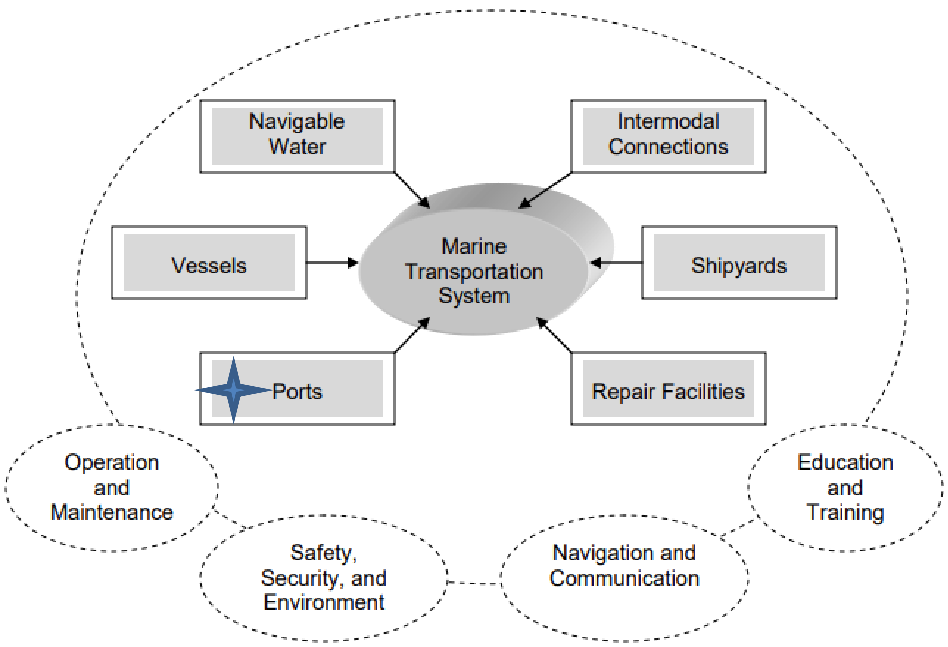


Figure 1: Marine Transportation System Components

Source: Easa et al., 2006

Advantages of maritime transport

Maritime transport as one of the oldest and most widely used modes of transport has many advantages. These include:

- **Cheaper rates**: Compared to other modes of transport, such as air, rail, or road, maritime transport is much more cost-effective, especially for long distances and large volumes of cargo. Across Logistics (2022) indicates that shipping offers the most competitive freight rates to shippers, as the maintenance cost of ships is much lower than other vehicles. For example, air transport delivery costs are typically 4 to 6 times higher than ocean freight (Blue Oceans Magazine, 2020).
- **Flexible and spacious vessels**: Maritime transport can accommodate a wide range of cargo types, sizes, and shapes, from bulk commodities like oil, coal, or grain, to containerized goods like electronics, clothing, or furniture. Ships can also carry oversized or heavy items that are difficult or impossible to transport by other modes, such as automobile parts, machinery, or industrial equipment (Blue Oceans Magazine, 2020). The largest containership can carry 18,000 containers, and one container can hold 10,000 beer bottles (Blue Oceans Magazine, 2020).

- **Key to foreign trade**: Maritime transport has a long history and tradition of connecting different international markets and facilitating cross-border trade. It is the main mode of transport for global trade, as it allows the movement of large quantities of goods across oceans and continents. Maritime transport has also established and planned the most important and effective trade routes in the world, such as the Suez Canal, the Panama Canal, or the Strait of Malacca (Blue Oceans Magazine, 2020).
- **Environmental performance**: Maritime transport is one of the most environmentally friendly modes of transport, as it has a low carbon footprint and consumes less fuel than other modes, such as airplanes, trains, or trucks. Shipping represents 2.6% of overall greenhouse gas emissions, while air transport accounts for 12% (Across Logistics, 2022). Shipping is also the least environmentally damaging form of commercial transport, and has reduced its marine pollution significantly in the last 15 years, despite a massive increase in global seaborne trade (Across Logistics, 2022)

Vulnerabilities in the MTS

Maritime transportation systems (MTS) are responsible for the transportation of most of the global overseas trade. Maritime transportation is dominantly concentrated on freight since there is no other effective alternative to the long-distance transportation of large amounts of freight. The volume of maritime transportation is constantly on the rise and is expected to continue to grow in the foreseeable future. Increasingly reliant on longer, larger, and more complex supply chain systems, the result is a system that is more prone to being vulnerable to physical, economic, and environmental changes. These systems are essential for world trade and thus it is crucial to understand vulnerability in these systems to be able to maintain their capacity and build resilience. In this context, the maritime transportation system is seen as a throughput mechanism - a technical system which serves its purpose by moving goods for its dependents. Understanding which key functions and capabilities are prerequisite for the ability to move goods.

According to the U.S. Department of Transportation's Bureau of Transportation Statistics, the total value of marine freight increases significantly every decade, with significant growth in military operations that use maritime transportation system facilities, waterways, and resources. The system is key to national and economic security as about 99% of U.S. international trade by volume moves through the nation's ports (USDOT, 2020).

The Mississippi River is a major part of the MTS and has been referred to as 'America's inland hydro highway' (Margolis, 2019). It is the second-longest river and major river of the second-largest drainage system on the North American continent. Figure 2 shows its course, watershed, and major tributaries. From northern Minnesota, it flows south for roughly 2,320 miles to the Mississippi River Delta in the Gulf of Mexico. The Mississippi ranks as the fourteenth-largest river by discharge in the world and is a critical food security corridor. Considered one of humanity's greatest civil engineering feats, the Mississippi functions as a major trading thoroughfare for US goods and commodities to and from the rest of the world.

Figure 2: The Mississippi River

Source: https://en.wikipedia.org/wiki/Mississippi_River_System

However, the strain on the river system is only becoming more acute with the impacts of climate change. New pressures are being put on the river, impacting transport, the environment and wildlife, as well as cities and towns along the river. Of interest is the impact of these pressures, particularly the creation of transportation infrastructure bottlenecks and vulnerabilities to the food and agriculture supply chains. These inherently complex supply chains due to their interdependency with critical infrastructure systems, including maritime and multimodal transportation, are at risk because of inadequate infrastructure and climate change

The first of its kind report, *Chokepoints and Vulnerabilities in Global Food Trade,* (Bailey and Wellesley, 2017) point to trade chokepoints – maritime, coastal, and inland – as an underexplored and growing risk to global food security. Maritime chokepoints, in particular, the report contends, will become increasingly fundamental to meeting global food supply particularly as with population growth and fluctuating dietary habits. Severe interruption at a chokepoint could trigger dramatic supply shortfalls and price spikes, with major consequences that could reach beyond food markets. While everyday disruptions may not in themselves trigger crises, they can add to delays, spoilage and transport costs, constraining market responsiveness and contributing to higher prices and increased volatility as well. The report also claims that expanding trade volumes, increasing dependence on imports, underinvestment, weak governance, climate change and emerging disruptive hazards together make both small-scale and large-scale chokepoint disruptions increasingly likely (Bailey and Wellesley, 2017). Climate change, however, will have a compounding effect on chokepoint risk, increasing the probability of both isolated and multiple concurrent weather-induced disturbances. Investment in infrastructure lags demand growth and chronic underinvestment in infrastructure is creating deficits in trade volume capacity and in resilience to climate change. According to the USEPA (n.d.), a large majority of the US's inland waterways are old, congested, and vulnerable to drought and flood with the Gulf Coast ports especially vulnerable to hurricanes and storm surges. The US needs to mobilize significant investment in the short term to provide new and smart infrastructure, alleviate bottlenecks and decrease vulnerability to climate change. Enhancing the evidence around the importance of chokepoints to food security, and the awareness of the nature of hazards and vulnerabilities are key steps in converting chokepoint analysis into policy and action.

Maritime Infrastructure – Ports

Ports are key features of the MTS system, serving as points of entry and exit of most of the goods imported into and exported from the United States (Wendler-Bosco and Nicholson, 2020). Table 2 shows the key port components and their impact on port infrastructure according to the 2023 Port Performance Freight Statistics Program's Annual Report to Congress (Bureau of Transportation Statistics, 2023). The table describes their significance as well as barriers to importing and exporting operations.

Table 2: Key Port Components & Their Impact on Port Infrastructure

Component	Description	Connection to Throughput and Capacity
Berth	A place to stop and secure a vessel for cargo transfer or other purposes. Berth locations are often determined by the availability of securement points on the wharf and may not have fixed sizes or boundaries.	The length of berths is significant for container and break-bulk terminals, where the full length of the vessel must be accessed. Berth length is less significant for bulk and Ro/Ro terminals, where unloading and loading operations use conveyors, ramps, or other means that do not involve the full vessel length. Insufficient berth availability can result in vessels waiting to be unloaded and loaded.
Waterside access	The waterways, channels, reaches, and anchorages that enable vessels to reach a port.	Limited waterside access can constrain the number and size of vessels that can call at a terminal.
Channel	A designated navigable waterway leading from open water to port terminals. Many channels have had sediment and other materials removed from the bottom of the channel (a process known as dredging) to accommodate larger vessels, and require periodic maintenance dredging to keep them clear.	The shallowest point of a channel can be a limiting factor on the size of ships that can access a terminal. Channel access may also be limited by air draft restrictions imposed by bridges.
Terminal	A port facility where vessels are discharged or loaded. Terminals can be defined by their facilities, equipment, the type of cargo handled, physical barriers or boundaries, ownership or operating structure, and other characteristics. Terminals may be operated by a port authority, independent marine terminal operators, vessel operators, or private companies handling their own cargo.	Many ports contain numerous terminals, each with its own berths, equipment, and landside storage space, and which may be adjacent to each other or separated by many miles. Terminals vary widely in configuration and infrastructure, and the number and size are therefore not consistent indicators of port capacity. However, terminal design, size, and infrastructure availability have a significant impact on both throughput and capacity.
Loading and unloading equipment	The fixed or mobile terminal equipment needed to handle different vessel and cargo types.	Cargo and vessel types vary greatly. Most container vessels are loaded and unloaded with shore-side gantry cranes ("container cranes"). Smaller vessels and barges may be handled with on-board equipment ("ship's gear") or with mobile harbor cranes. Ro/Ro vessels and barges are loaded and unloaded via ramps. Bulk and break-bulk terminals use a combination of fixed and mobile equipment that typically allows for faster loading and unloading of a vessel, but operations may still be limited by landside infrastructure and operational efficiency.

Source: 2023 Port Performance Freight Statistics Program: Annual Report to Congress

Ports are also important nodes in intermodal transportation systems, connecting maritime transportation to rails and roads. The United States' 361 ports serve as major economic drivers and places of employment. In 2017, foreign trades through U.S. ports were valued at $1.6 trillion—$527 billion exports and $1.1 trillion imports were moved by vessels (AAPA, 2020). According to the American Association of Port Authorities (AAPA, 2020), in 2018 seaports contributed $5.4 trillion to the economy, approximately 26% of the total GDP. AAPA (2020) estimates that 30.8 million jobs were supported by ports in 2018, in comparison to 23.1 million in 2014. In addition, specific ports around the United States are designated as "strategic seaports" because of their ability to support major force and materiel deployments in times of war and national emergency.

According to the American Association of Port Authorities, deep water ports in the U.S. supported 541,946 jobs in 2014. In addition, port activity generated over 23 million jobs in related sectors and through their overall economic impact on the surrounding communities. MTS (2021) indicates that this waterborne cargo and associated activity now contributes more than $500 billion dollars to the GDP of the United States, generating well over $200 billion in annual port sector federal/state/local taxes and sustaining over 10 million jobs. According to vessel and air data of the Department of Transportation, vessels moved 41.9 percent of the value and 70.7 percent of the weight of U.S. international trade in 2018 (Bureau of Transportation, 2023).

An EPA an article titled "Ports Primer:2.1 The Role of Ports" notes that American ports are gateways for US and international trade with over 95% of the cargo entering the U.S. being transported by maritime transportation and 99% of the country's overseas cargo by volume (USEPA, 2023). These ports are very vital to the American way of life not just in transporting goods, which stimulates the national economy, but also to national defense and homeland security. Ports serve as a major employment, and economic stimuli providing significant job opportunities in towns around the nation. USEPA (2023) showed that by 2018, seaports cargo activity supported the employment of approximately 31 million people in the United States - an increase of 7.5 million jobs since 2014. EPA also showed that seaport-related jobs in 2018 provided for $1.4 trillion in personal income and local consumption and that for every $1 billion in exports shipped through U.S. seaports, 15,000 jobs are created. Cargo activities at U.S. seaports account for 26 percent of the U.S. economy, generating nearly $5.4 trillion in total economic activity and more than $378 billion in federal, state, and local taxes in 2018 (USEPA, 2023).

Importance of Ocean Ports to Agricultural Trade

Ports are essential to agricultural export. U.S. ocean ports provide the gateway for an estimated 70 percent of U.S. agricultural exports and 60 percent of agricultural imports. (American Farm Bureau Federation, n.d). Figure 3 shows that California ports are responsible for shipping over 75% of U.S. exports of tree nuts, oranges, and prepared tomatoes, more than 60% of cotton and hides and over 30% of dairy exports. The Port of Savannah in Georgia moves 42% of total U.S. containerized poultry exports and an additional 30% of cotton, while Virginia ports process over 75% of tobacco exports.

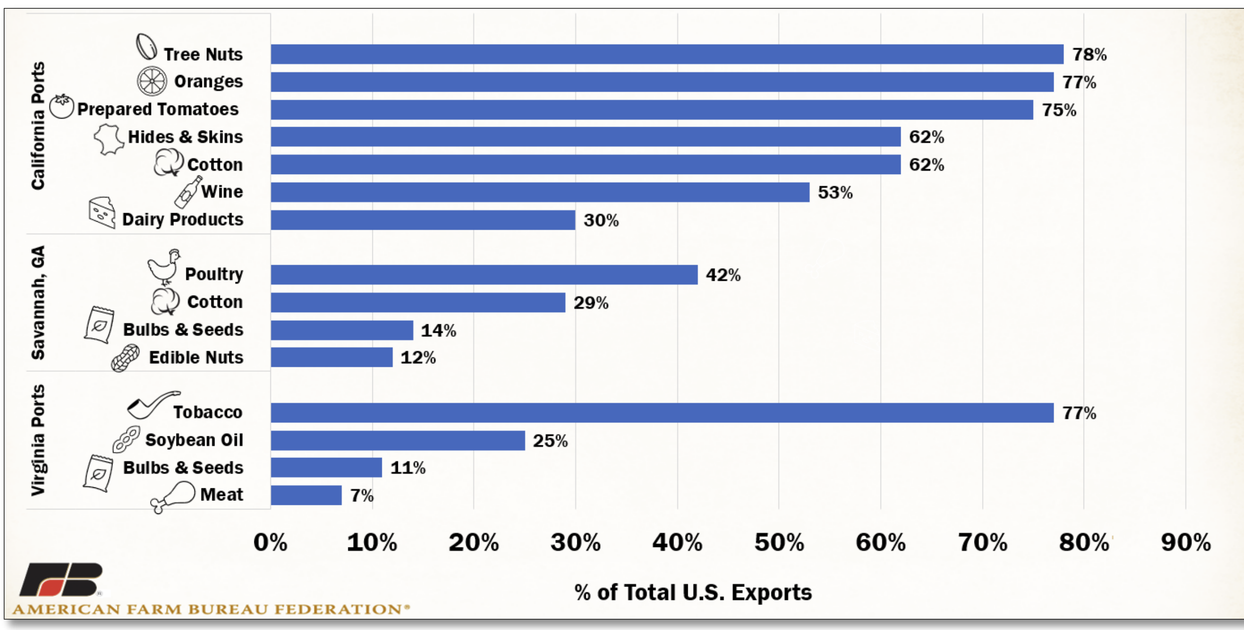


Figure 3: Share of US Agricultural Exports by Selected Port and Commodity
Source: American Farm Bureau Federation & USDA AMS

U.S. ports and the maritime industry offer access to a vast global marketplace to agricultural shippers and exporters. One of the major catalysts behind stronger farm income over time has been the strength of U.S. agricultural exports. According to Blanton (2017), Director Transportation Services Division, Agricultural Marketing Service of the U.S. Department of Agriculture:

- About 75% of U.S. agriculture exports are shipped by ocean (28% in containers)

- The Gulf and Pacific Northwest are major ports for U.S. grains
- Approximately 7% of U.S. grain exports are in containers
- Container Ships - Increasing ship size, carrier alliances and consolidation
- Container and bulk vessel market characterized by low rates and over-capacity

U.S. agricultural trade had been largely dominated by exports. USDA's Grain Inspection, Packers and Stockyard Administration data show that 57 percent of U.S. grain exports departed through the U.S. Gulf region in 2008 (American Marketing Service, 2009). According to AMS (2009), the top 10 export ports for U.S. waterborne agricultural trade by tonnage at that time were:

- South Louisiana (21%)
- New Orleans (17%)
- Tacoma (6%)
- Kalama (6%)
- Seattle (5%)
- Houston (5%)
- Portland, OR (5%)
- Westwego (5%)
- Los Angeles (3%)
- Vancouver, WA (3%).

According to the Agricultural Marketing Service's June 2019 report, by 2017, more than 197 million metric tons (mmt) of waterborne agricultural cargo valued at over $153 billion moved through U.S. seaports and the top five ports by volume were:

- New Orleans Ports Region (37%)
- New York/New Jersey (5%)
- Kalama (5%)
- Los Ángeles (5%)
- Tacoma (4%)

Together, these five ports represented about 56 percent of the waterborne agricultural trade in 2017. The New Orleans Port Region was the leading seaport, moving 47 percent of the total exports and 37 percent of total waterborne agricultural trade. In 2017, the New Orleans Port

Region was the top U.S. port region for moving agricultural trade - 70.6 mmt for exports and 1.95 mmt for imports (Agricultural Marketing Service, 2019). Figure 4 shows the top 20 US ports that move waterborne agricultural trade exports per 1,000 metric tons in 2017 also with the New Orleans Port Region as the leading seaport. The New Orleans Port Region includes South Louisiana, New Orleans, Baton Rouge, Avondale, St Rose, Gramercy, and Destrehan, LA.

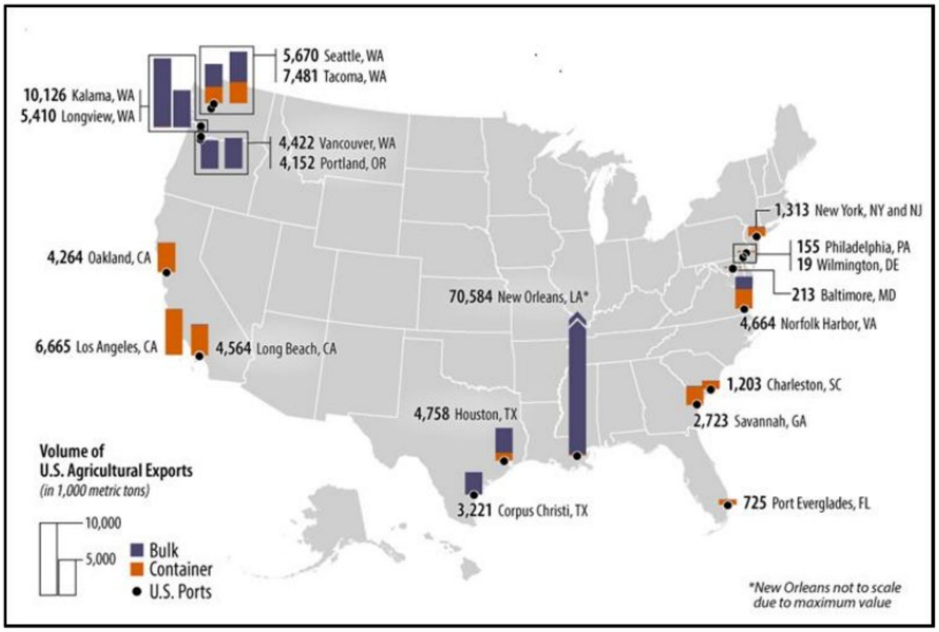


Figure 4. Top 20 U.S. Ports Moving Waterborne Agricultural Trade Exports in 1,000 Metric Tons, 2017

Source: USDA, AMS, Profiles of Top U.S. Agricultural Ports, June 2019.

According to Regmi (2021), U.S. agricultural exports exceeded imports every year between 1967 and 2019; the year 2019 was when imports were higher than exports for the first time (Figure 5). The faster-paced growth in the value of U.S. agricultural imports contributed to a decline in the U.S. agricultural trade surplus from $16 billion in 2016 to $4 billion in 2020. Almost 70% of the value of U.S. agricultural exports was accounted for by the top 15 categories of products, with soybeans making up over 14% of the total and corn 6.8% shown in Table 3 (Regmi, 2021).

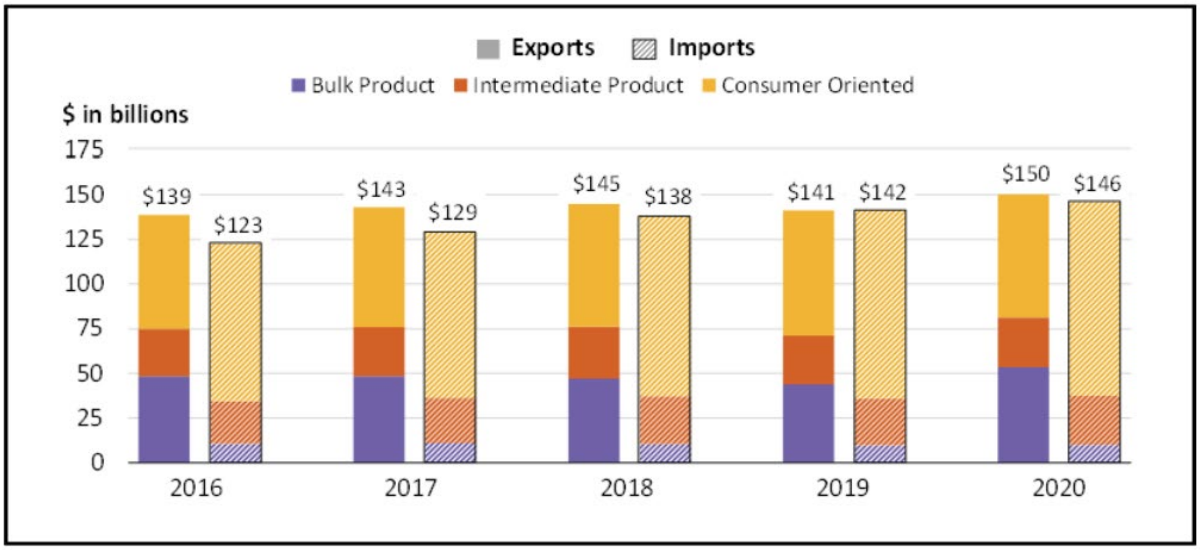


Figure 5. Value of U.S. Agricultural Trade, 2016-2020 In Billions of Dollars

Source: Regmi (2021)

Table 3. Top U.S. Agricultural Export Products by Value Annual Average Exports of $145.3 billion from 2018 to 2020

Rank	Product	$ Billions	Share of Total
1	Soybeans	20.5	14.1%
2	Corn	9.9	6.8%
3	Tree nuts	8.7	6.0%
4	Beef products	7.9	5.4%
5	Pork products	6.7	4.6%
6	Dairy products	5.9	4.1%
7	Wheat	6.0	4.1%
8	Cotton	6.2	4.3%
9	Soup & other preparations	5.7	3.9%
10	Soybean meal	4.7	3.3%
11	Fresh fruit	4.5	3.1%
12	Poultry (excluding eggs)	4.1	2.8%
13	Bakery & cereal products	3.5	2.4%
14	Feeds & fodders	3.0	2.1%
15	Processed vegetables	3.0	2.1%
	Other products	45.1	31.0%

Source: U.S. Census Bureau Trade Data, via USDA, FAS, accessed March 2021, at https://apps.fas.usda.gov/gats/default.aspx

The composition of U.S. agricultural exports varies across U.S. trading partners. Table 4 shows Canada, Mexico and China as the top agricultural destinations for US exports.

Table 4. Top U.S. Agricultural Destinations by Value Annual Average Exports of $145.3 Billion from 2018 to 2020

Rank	Country	$ Billions	Share of Total
1	Canada	22.0	15.2%
2	Mexico	19.0	13.1%
3	China	16.5	11.4%
4	Japan	12.3	8.5%
5	EU-27	11.2	7.7%
6	South Korea	8.0	5.5%
7	Vietnam	3.7	2.5%
8	Taiwan	3.6	2.5%
9	Philippines	3.1	2.1%
10	Hong Kong	3.0	2.1%
11	Indonesia	2.9	2.0%
12	Colombia	2.9	2.0%
13	Thailand	1.9	1.3%
14	India	1.9	1.3%
15	Egypt	1.8	1.2%
	Other Countries	31.5	21.7%

Source: U.S. Census Bureau Trade Data, via USDA, FAS, accessed March 2021, at https://apps.fas.usda.gov/gats/default.aspx.

According to the Organisation for Economic Co-operation and Development (OECD, 2020), changes in global food consumption patterns over the last decade were largely driven by shifts in individual consumer preferences (per capita demand) rather than population growth (Figure 6). The OECD projects that population increase will matter even less over the next decade.

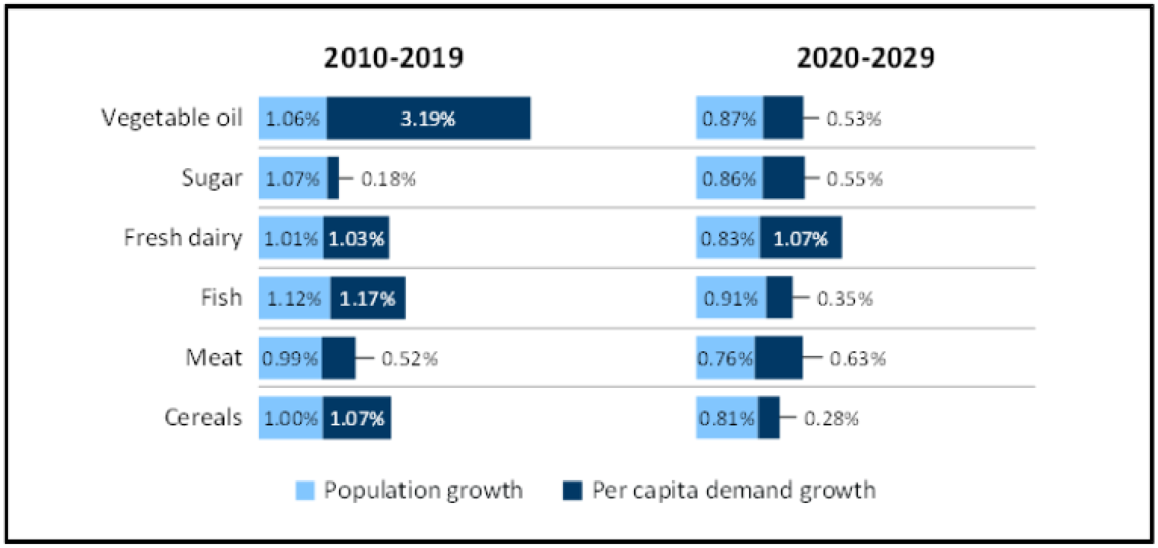


Figure 6. Annual Growth in Demand for Selected Food Categories Percentage Growth, 2010-2019 Versus 2020-2029

Source: OECD, 2020

Vulnerabilities of Ports

Vulnerability is defined as the degree to which a system, or part of it, may react adversely during the occurrence of a hazardous event. The concept implies a measure of risk associated with the physical, social, and economic aspects and implications resulting from the system's level of capability to cope with the resulting event (Proag, 2014). Due to the very nature of their location, seaports are highly exposed to climate change and are often ill-prepared for the effects of these disruptions. Because they are also choke-points of global trade handling 80% of the world's goods, disruptions can have far-reaching consequences. A September 2020 report by the Economist (n.d.) indicated that after Hurricane Katrina shut down three ports that processed 45% of America's agricultural goods, national food prices rose by 3% and that Hurricane Harvey had a similar effect on the price of fuel. Ports are highly vulnerable to risks of sea-level change which can magnify the impacts of coastal hazards, threatening the resilience of ports. Seaports and port infrastructure do not have the option to relocate, as their functionality depends on their coastal location (Asariotis and Benamara 2012). Officials from the Port of Virginia are expecting a sea level rise increase of a foot and a half within the next 30 years, triggering them to invest in raising electrical power stations and moving data servers farther away from the water's edge (Vogelson, 2021).

Nicholls (2008) analyze port vulnerability and suggest specific adaptation strategies such as storm surge barriers including seawalls and dikes for port stakeholders (). Many ports, however, do not have the proper procedures in place. According to the Economist (September 2020), the World Association for Waterborne Transport Infrastructure highlighted a recent survey that asked 67 ports if they had performed climate-risk assessments, installed early-warning systems, or made contingency plans. Only 15% had done all three and over one-fifth had done none.

Table 5 shows an example of matrix of potential climate change impacts for transportation infrastructures. The matrix is a simple and clear way to identify the risks due to changes in temperature, precipitation, and sea levels. Table 6 identifies climate variables impacts on open sea, estuarine and inland waterway ports.

Table 5: Matrix of Potential Climate Impacts on Transportation

Climate change	Roads	Railways	Ports and Waterways	Airports
Temperature change	• Rapid asphalt deterioration • Substructure damage • Increase O&M costs.	• Expansion and buckling of railway tracks joints.	• Thermal expansion of bridge joints, paved surfaces	• Asphalt deterioration on runway
Precipitation change	• Increase flooding of roadways • Increase erosion • Construction damage	• Increase flooding of stations	• Channel closure due to increased silt deposition due to flooding • Reduce navigability	• Travel disruption due to flooding • Damage to airport infrastructure due to inundation
Sea level rise	Permanent inundation of road, port, and airport infrastructure			

Source: Pudyastuti, P. and Nugraha, N. (2018)

Table 6: Summary of major climate variable and their impacts on ports

Climatic Factor	Impacts on open sea, estuarine and inland waterway ports
Sea level (mean and extreme)	
(i) mean sea level changes; (ii) increased destructiveness of storm surges/waves; (iii) changes in the wave energy and direction	Damages in port infrastructure/cargo from incremental and/or catastrophic inundation and wave regime changes; higher port construction/maintenance costs; potential modulation of tides causing sedimentation/dredging in port/navigation channels and operational time table changes; effects on key transit points; increased risks for coastal road/railway links; relocation of people/businesses; insurance issues
Temperature	
Higher mean temperatures; (ii) heat waves and droughts (iii) increased spatio-temporal variability in temperature extremes	Damage to infrastructure/equipment/cargo and asset lifetime reduction; increases in the staff health risk; higher energy consumption for cooling terminals and cargo; restrictions for inland navigation that may affect estuarine port competitiveness (e.g. port of Rotterdam); reductions in snow/ice removal costs; extension of the construction season; changes in transport demand
In arctic areas, permafrost degradation and reduced arctic ice coverage	Major damages in infrastructure; coastal erosion affecting road and rail links to ports Longer shipping seasons-NSR; new shorter shipping routes-NWP/less fuel costs, but higher support service costs
Precipitation and Fog	
Changes in the mean and the intensity and frequency of extremes (floods and droughts)	Land infrastructure inundation; damage to cargo/equipment; navigation restrictions in inland waterways; network inundation and vital node damage (e.g. bridges); problems in port equipment operations (e.g. cranes); changes in demand
Increases in fog intensity/duration	Impact on ship and terminal operations (reduced visibility)
Wind	
Extreme harbour winds	Problems in seaport navigation and berthing; operational disruptions due to inability to load/unload

Source: UNCTAD Research Paper No. 18

Aging infrastructure is also a major issue faced by ports. Many locks in the United States were built in the 1930's and their average age exceeds 50 years. Waterway systems transport delays, back-ups and added costs are common events for barges and tows due to aging infrastructure and under investment in modernization. Energy Infrastructure (n.d.) reports that according to the Army Corps of Engineers, "Long-established programs for advance maintenance of principal lock components have essentially given way to a fix-as-fail policy, and even then the fix may take weeks or months to complete. Depending on the nature of the lock malfunction, this protracted repair time can have major consequences for barge traffic that depends on the facility, and for shippers and manufacturers depending on timely delivery of their cargo."

According to the American Society of Civil Engineers 2017 Infrastructure Report Card, public infrastructure has been neglected, a fundamental issue in infrastructure resilience. Based on their analysis, the total funding needs for dams, levees, waterways, and ports extended to 2025 (in 2010 dollars) is $162B. The estimated available funding is $38B with a funding gap of $124B or 76.5% (See Figure 7 and Table 7). This is the highest funding gap of all of the infrastructure types.

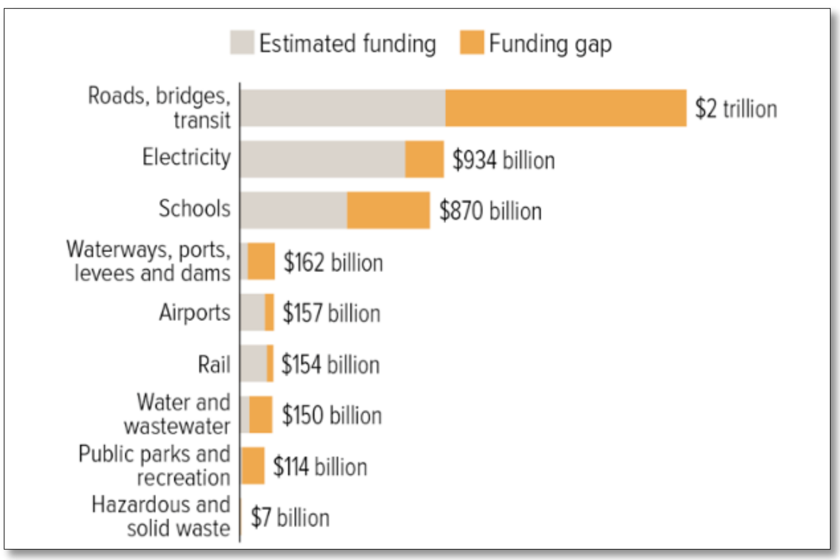


Figure 7: Infrastructure Needs, Funded and Unfunded, 2016 - 2025
Source: American Society of Civil Engineers 2017 Infrastructure Report Card

Table 7: Cumulative Infrastructure Needs by System Based on Current Trends Extended to 2025 (dollars in 2010 billions)

Infrastructure Systems	Total Needs	Estimated Funding	Funding Gap
Roads, Bridges, & Transit[1]	$2,042	$941	$1,101
Electricity[1]	$934	$757	$177
Schools[2]	$870	$490	$380
Public Parks & Recreation[3]	$114	$12	$102
Airports[1,4]	$157	$115	$42
Dams, Levees, Waterways & Ports[1,5,6]	$162	$38	$124
Water & Wastewater[7]	$150	$45	$105
Rail[8]	$154	$125	$29
Hazardous & Solid Waste[7]	$7	$4	$3
Total	$4,590	$2,526	$2,064

Source: American Society of Civil Engineers (ASCE) 2017 Report Card

The fact that so many rely on port functionality to prosper in the U.S. it is essential to understand port limitations. Limitation such as physical impediments movement of goods through ports, such as shallow depths that limit the size of ships, the lack of access to interconnecting modes of transportation, or the narrowing of channels that increase the risk of ship collisions can cause significant delays and incur tremendous costs to shippers and consumers. Understanding potential physical choke points at ports is critical to shippers, port operators and the owners of goods to ensure transportation routes are managed safely and efficiently.

The American Farm Bureau Federation (n.d.) contends that a key challenge for marine ports particularly on the East and Gulf Coasts, will be their ability to handle the large post-Panamax cargo ships. These vessels are 40% longer, 64% wider and have more than 2.5 times the cargo capacity of the current Panamax vessels. The Panama Canal was expanded in June 2016 and created waves of change around the world as the maritime industry continued to react to larger ships with nearly tripled cargo capacity. The widening and deepening of the canal led to the creation of the Neopanamax, or New Panamax, size limits for ships to safely travel through the canal. Based on new lock dimensions the canal now accommodates ships with a 1,201-foot length, 160-foot beam, 50-foot draft, and a capacity of 14,000 20-foot equivalent units (TEUs), the size of a standard shipping container. Its previous maximum was ships 950 feet in length, with a 106-foot beam, 39.5-foot draft, and 5,000 TEU capacity. Naval architects and ship builders have been scrambling to construct new cargo ships to appease shippers, and ports are working diligently to update their facilities to accommodate the larger vessels. The shift has been so dramatic that according to the BBC, pre-expansion or "old Panamax" ships, some less than a decade old, have been sold for scrap. Several U.S. ports, including New York and New Jersey, Miami, Norfolk and Baltimore, have or are in the process of increasing their wharfs' depths to 50 feet to accommodate the new ships. Ports in Jacksonville, Florida, Savannah, Georgia, and Charleston, South Carolina, are considering going to 50 feet, and Mobile, Alabama, recently dredged to 45 feet.

According to the study "The Economic Impact of Deepening the Mississippi River to 50 feet," co-sponsored by both the Big Rivers Coalition (BRC) and the Louisiana Department of Transportation and Development (DOTD), a 50-foot depth expansion of the Mississippi would provide a $96.8 million annual benefit to the U.S. economy (Price, 2018). The dredging project was estimated at $238 million; the DOTD would pay approximately $120 million, with annual maintenance and operating costs paid by the federal government. According to the study the U.S. economy would add 17,000 jobs because of the increase in production and $849.5 million in increased income for American workers (Price, 2018). The BRC is a collection of more than 110 maritime businesses, trade associations and port authorities that do business on the Mississippi River and its tributaries. Sean Duffy, the Executive Director of the BRC explained that the Coalition had often discussed the importance of the Mississippi River to the American farmers, as the ship channel connects over 350 million acres of agricultural lands to international markets. Duffy said. "American farmers export up to 70 percent of U.S. agricultural exports to world markets via waterborne commerce on the Mississippi River, and the ship channel deepening project offers significant reductions in shipping costs." On July 31, 2020, the U.S. Army Corps of Engineers and the State of Louisiana signed an agreement to deepen the Lower Mississippi River from 45 feet to 50 feet.

Planning for Resilient Infrastructure

Proag (2014) indicates that a system is usually designed to behave in a certain way under normal circumstances, however, when disturbed from equilibrium by a disruptive event, the performance of the system will deviate from its design level. A system's level of resilience is dependent on its ability to reduce both the magnitude and duration of the deviation as efficiently as possible to its usual targeted system performance levels. Resilience of complex systems has emerged as a fundamental concern for system managers, users, and researchers. Transport networks are susceptible to a wide range of vulnerabilities that can lead to operational degradation (Srinivasan, 2002). Given the vital importance of their infrastructure to society's social and economic well-being, it is imperative to ensure networks are strong, secure, and resilient.

Several definitions of resilience have existed in the literature since Hollings' conceptualization of resilience for the field of ecology in 1973. Researchers have applied the concept to their respective fields by proposing and adopting definitions and terminologies more suitable for their areas. Table 8 shows several definitions from the last decade which are most related to critical infrastructures.

Table 8: Selected Definitions of Resilience

Reference	Year	Definition
Vugrin et al.	2011	Ability to have minimum deviation in value and time required to achieve targeted level of performance after a particular disaster
Henry and Ramirez-Marquez	2012	Ability of an entity to recover from an external disruptive event
Keogh and Cody	2013	Ability to avoid functional interruptions during a disastrous phenomenon
Faturechi and Miller-Hooks	2014	Ability to absorb changes that are induced externally as well as ability to adapt post-event conditions
Panteli and Mancarella	2017	Ability to forecast, endure, survive, and quick recovery from a disaster.
Liao et al.	2018	Indicator of system performance under an unexpected event.
Dick et al.	2019	Ability to lessen disturbances to regain or sustain operation predictable and unpredictable conditions

Source: Nipa, T. J. and Kermanshachi, S. (2019)

In its simplest form, infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. It is a key factor in the maintenance of the functionality of critical infrastructure systems and characterizes the ability of these systems to lessen the intensity of impacts caused by a disruptive event and to reduce the length of their failure or disruption. In October 2009, the National Infrastructure Advisory Council (NIAC or Council) issued Critical Infrastructure Resilience, a study that examined how critical infrastructures could become more resilient. In February 2010, the Department of Homeland Security (DHS) published the Quadrennial Homeland Security Report: A Strategic Framework for a Secure Homeland (DHS, 2010) core resilience objectives is Infrastructure resilience: "Enhance the ability of critical infrastructure systems, networks, and functions to withstand and rapidly recover from damage and disruption and adapt to changing conditions." The study also noted that "resilience policy cannot be applied equally to all sectors but rather understood and analyzed on a sector-by-sector basis, taking into consideration the complexity of existing regulatory and voluntary protection programs, the fundamental nature of the sector, and the cost and benefit of potential resilience programs" (Berkeley and Wallace, 2010)

Transportation infrastructure resilience measuring dimensions

Nipa, T. J. and Kermanshachi, S. (2019) contend that the literature had only focused on a limited number of resilience dimensions and had not investigated all aspects of resilience characteristics for transportation infrastructures. Therefore, they developed a comprehensive conceptual model to determine the relationships of resilience dimensions in critical and interdependent transportation infrastructures. Eighteen dimensions of resilience including robustness, redundancy, and resourcefulness were identified (Table 9).

Table 9. Dimensions of Resilience

#	Dimensions	Explanation
1	Robustness	System must be strong enough to absorb the disturbance when exposed to disastrous events; a strong and healthy system will have higher robustness.
2	Redundancy	Allows system to have multiple back-up components with same functionality
3	Resourcefulness	The availability of material and human resources to achieve recovery after a disaster
4	Rapidity	Speed of the system to be recovered to the functionality after a disaster
5	Efficiency	Characteristic of the system that optimizes input-output ration of energy of a system
6	Diversity	Characteristic that allows the system to have back-up components with different kinds of functionality to able to withstand multiple types of disasters and threats.
7	Autonomous components	Have ability to independently function without any control from outside
8	Collaboration	Characteristic enables a system to have the ability to share information and resources among stakeholder or components
9	Mobility	Characteristic indicates that the system will be able to provide an acceptable level of service
10	Safety	System must be safe enough for the users so that users do not get exposed to the hazards
11	Strength	It is the inherent power of the system to resist outside attack
12	Vulnerability	Physical weakness of the system to a disruptive event with a negative impact on the speed of the loss of performance during a disaster
13	Adaptability	Ability of the system to adopt lessons from the current disaster which will help the system to be resilient against future disaster
14	Flexibility	Measures the ability of the system to adapt itself to the impact of disaster through emergency plan.
15	Survivability	Ability of the transportation system to endure the initial impact of the disaster to continue the service
16	Preparedness	Ability to have certain measures which will help the system in dealing with the disaster
17	Reliability	Indicates the probability of continuing normal operation all the times
18	Responsiveness	Ability of the system to recognize the changes that occurred due to a disastrous event

Source: Nipa, T. J. and Kermanshachi, S. (2019)

Port of New Orleans – Infrastructure & Bottlenecks

The Mississippi River and its tributaries connect 31 states and two Canadian provinces through the third largest river basin in the world, all which funnels through southeastern Louisiana.

Collectively, the five deep-water ports on the lower Mississippi River — New Orleans, South Louisiana, Baton Rouge, St. Bernard, and Plaquemines — comprise the busiest port complex in the world handling more tonnage than any other port in the world, providing billions of dollars in annual economic impact and supporting hundreds of thousands of jobs (Price, 2018).

The Port of New Orleans (Port NOLA), a deep-water port and multimodal gateway located on the Mississippi River near the Gulf of Mexico, connects global markets to and from the U.S. and Canada. Port NOLA is one of the largest ports in the United States. It is located on both sides of the Mississippi River with its boundaries encompassing the parish of Orleans and the river frontage of the parishes of St. Bernard and Jefferson. Port NOLA has access to 30-plus major inland hubs such as Memphis, Chicago and Canada via 14,500 miles of waterways through the Mississippi River and its tributaries, six Class I railroads and interstate roadways. Port NOLA's facilities include 40 berths, 20 million square feet of cargo-handling area, six ship-to-shore gantry cranes, more than 3.1 million square feet of covered storage area, and 1.7 million square feet of cruise terminal and parking facilities. The port is mainly a general cargo port. It has over 28 miles of public and private wharves and other related facilities with public docks that can handle as many as 85 ships at any one time. Most of the wharves along the waterfront of the city of New Orleans are public facilities under the control of the Board of Commissioners of the Port of New Orleans. Almost all wharves have rail connections. Depths at the wharves range from 6 to 45 feet, with about 35 feet alongside most wharves. The frontage for deep-draft vessels within the port limits includes approximately 58 miles along the riverbanks, about 11.5 miles on the Inner Harbor Navigation Canal and the Mississippi River-Gulf Outlet Canal. The acquisition of New Orleans Public Belt Railroad strengthened the Port's position as an integrated supply chain hub and supports the vision for regional freight-based economic development.

Port NOLA considers their role as a property manager, to plan, build, maintain, and support the transportation infrastructure, growing jobs and economic opportunities related to trade and commerce. Together with their tenants, operators, and partners, Port NOLA considers that its collective strength is as an economic catalyst driving global trade and building local prosperity. As a self-sustaining political sub-division of the State of Louisiana, Port NOLA invites collaboration and pragmatic, strategic planning. The Port works diligently to collaborate with stakeholders and industry partners, within their tri-parish jurisdiction and beyond, for continued economic development. New Orleans is the only U.S. city where deep-draft shipping aligns with the rail gateway to make a truly intermodal freight source. Port NOLA connects Louisiana businesses to the world and creates family-supporting jobs. Port-related industries generate 1 in 5 jobs in Louisiana. The average salary of companies located on Port NOLA property is $74,000 per year — 51% higher than the average local salary.

Port Activities, Operations and Stakeholders

Table 10: Activities supported by the Port NOLA

Activities	*Port of New Orleans*
Imports	Yes
Exports	Yes
Fishing	No
Bulk Cargo	Yes
Liquid Bulk Transfer	No
Break Bulk	Yes
Containers	Yes
Ron On/Roll Off	Yes
Lift On/Lift Off	Yes
Ferries	No
Cruise Ships	Yes
Rail Terminals	Yes
Air Terminals	No
Research Vessels	No
Tugboats	No
Recreational Vessels	Yes
Shallow Draft Coastal Freighters	No

Port Tenants

There are currently 33 industrial tenants throughout Port NOLA's jurisdiction, and most are located on the Inner Harbor. The Inner Harbor consists of over 1,000 acres flanking the Inner Harbor Navigation Canal and Gulf Intracoastal Waterway. The Inner Harbor is located within 2.5 miles of Interstate 10, within 5 miles of Lakefront Airport, and 7 miles from New Orleans Central Business District. Most properties are served by NOPB with access to six Class I railroads**.** Tenant businesses at the Port of New Orleans include shipbuilding and repair; warehousing and distribution; truck and container depots; materials handling; steel distribution;

refrigerated warehousing; manufacturing; packaging; transloading to either rail, barge, or truck; bulk transloading, sorting, and packaging; and other value-added activities. In addition to the equipment, cranes, and bridges, Port NOLA owns and maintains over 18 miles of roadways; railroad tracks; and many more miles of water, sewer, and drainage infrastructure throughout the Port's jurisdiction. Port NOLA serves as an import hub for coffee, natural rubber, and steel.

Imports & Exports

Table 11 shows that the top communities for Port NOLA in 2020 were corn, up 47.2% from 2019, distillate fuel oil, soybeans, residential fuel oil and animal feed preparation. All commodities mentioned experienced growth between 2019 and 2020, with the exception of distillate fuel oil which decreased by 29.5%. In addition, the sum of all other communities also decreased by 16.2%. Top food and farm products in 2020 were corn, soybeans, animal feed prep, wheat, and oilseeds (not elsewhere classified).

Table 11: Port of New Orleans Commodities, 2020

Top Commodities in 2020 81,067,448 short tons of Total Tonnage			
Commodity	Short Tons	2019-2020	
Corn	9,281,970.00	47.2%	Up
Distillate Fuel Oil	9,155,203.00	29.5%	Down
Soybeans	8,759,824.00	17.8%	Up
Residual Fuel Oil	4,646,240.00	0.9%	Up
Animal Feed, Prep.	4,639,003.00	27.2%	Up
All Others	44,585,208.00	16.2%	Down

Top Food & Farm Products in 2020	
Corn	9,281,970.00
Soybeans	8,759,824.00
Animal Feed, Prep.	4,639,003.00
Wheat	1,461,167.00
Oilseeds NEC	1,445,294.00

Source: Port Performance Freight Statistics Program Port Profiles, 2022

Port NOLA's export volumes are due in part to the Port's participation in the large-volume Asia and European trade lanes, and with a growing share in emerging markets such as South/Central America and Africa. The increase in containerization of breakbulk and bulk contributes to the growth in Port NOLA's container business. Table 12 shows container volume exports and imports each year from 2016 through 2020. Trading at Port NOLA grew between 2016 and 2107, however, experienced uneven growth in the remaining time periods. There was a decrease between 2017 and 2018, an increase between 2018 and 2019 followed by a decrease during 2019 to 2020. Exports significantly trump imports at Port NOLA, in some cases tripling the amount of commodities that are imported.

Table 12: Container Volume of Imports & Exports, Port of New Orleans, LA

Port of NOLA	*Exports*	*Imports*	*Total*
2016	261,254.63	111,911.95	373,166.58
2017	296,357.30	109,994.15	406,351.45
2018	277,421.44	122,776.09	400,197.53
2019	297,304.11	136,883.29	434,187.40
2020	277,447.11	142,897.64	420,344.75

Source: Port Performance Freight Statistics Program Port Profiles, 2022

Table 13 shows vessel calls by type at the Port of NOLA. The Port of NOLA had mostly dry bulk vessel calls with 649 calls in 2020 and an average volume of 27,532 tons per vessel.

Table 13: Vessel Calls in 2020 & Regional Average, Port of NOLA

Container	*Vessel Calls*	*535*
	Avg. Volume/Vessel	786
Dry Bulk	Vessel Calls	649
	Avg. Volume/Vessel	27,532
Dry Bulk Barge	Vessel Calls	15,604
	Avg. Volume/Vessel	1,781
Other Barge	Vessel Calls	1,781
	Avg. Volume/Vessel	4,774
Other Freight	Vessel Calls	719
	Avg. Volume/Vessel	

Source: Port Performance Freight Statistics Program Port Profiles, 2022

Port NOLA is a modern deep-draft container terminal and the only container port in the State of Louisiana. The Napoleon Avenue Container Terminal has the capabilities and capacity to efficiently service the needs of ocean carriers and shippers. The Container Terminal complex has an annual capacity of 1 million TEUs with nine gantry cranes and an expansion footprint for up to 1.5 million TEUs per year with 12 gantry cranes. Container terminal operators New Orleans Terminal and Ports America provide stevedoring and transloading services. Table 5.9 shows that Port NOLA has 6 Post-Panamax (PPX) cranes which are modern port cranes larger than the Panamax cranes. They hold up to 16 containers on the cover and reach up to 45 meters with a lifting height of 35 meters. Like the Panamax crane, their workload ranges from 40-50 tons in a single raise and 65 tons in a double lift. They are used to load and offload containers from ships too large to pass through the Panama Canal.

Summary and Challenges for Port NOLA

Port Nola has been in operation for the past one hundred and twenty-five years and has withstood the test of time and has endured many devastating events including hurricanes, tropical storms, floods, recessions, and pandemics. The Port Authority indicated that the key to their success and longevity lies in their dedication to learning from each event and incorporating lessons learned into their infrastructure and operational plans. One of the most important lessons learned from their perspective is that no two events are the same. Plans need to have options to deal with all critical needs related to communications, operations, materials, and resources. Many things can be done to continue to improve their resilience and recovery processes and procedures including:

1. Dedication to improving communication options during and after an event such as hardened telecommunications networks and alternative means of communications.
2. Considerations to provide alternative Emergency Operations Center (EOC) locations to accommodate a variety of infrastructure impacts.
3. Continued communications and coordination with all stakeholders such as USACE, Coast Guard, Levee Districts, Pilot Organizations, Utility providers, Terminal operators, Shippers, and others.
4. Improvements in operations visibility to effectively communicate needs and priorities to all stakeholders so we can share resources in support of each other in recovery.

5. Consider options to diversify business lines to offset economic impacts.
6. Consider resilience upgrades and modification options in all restoration activities.
7. Adopt and adhere to current building codes for all new construction.
8. Consider resiliency-related concerns in all master planning activities.

Common strategies for resilience building include long-range planning; construction and design strategies (on and off port lands); preparations, response, and recovery. Some ports could benefit from the acquisition of adjacent lands and properties or the acquisition of insurance coverage (Becker and Caldwell, 2015). Port NOLA may want to consider additional satellite facilities, such as container depots and inland terminals, to allow for port operations support, relieving congestion, and offering a buffer to accommodate volatility. Off-site office facilities can accommodate the additional managerial workforce and, particularly, offer a location where management can operate if the on-terminal office facilities are forced to temporarily close.

Port NOLA officials have acknowledged that they could be better at preparedness which could involve the positioning of equipment, parts, and material to replace or repair damaged facilities. Preparedness also identifies key personnel that need to be available to operate the terminal and repair damaged infrastructure and equipment. Although at the costs of duplication and a higher inventory, this would improve the restorative capacity of the port terminal. The key challenge, of course, would be to determine what quantity to store with a view to potential risks and disruptions to build redundancy in operations and infrastructure.

Additional breakwater, access channels, basins, and/or turning basins are options that the ports may consider improving the physical structure of the facilities to withstand natural hazards; these would also enable the port to better cope with technical changes in ship design, especially economies of scale. In November 2017, USACE released a Record of Decision on the Gulfport Expansion project, paving the way for the port's next significant expansion, including a 282-acre dredge and fill program for expansion of the West and East Pier Terminals, and a 4,000 linear foot breakwater system. The use of traffic diversion strategies that consider the closure of elements of the port, such as a specific terminal or an access corridor. The ultimate strategy is to consider a complete traffic diversion if the port is forced to close for a period of time because of serious disruptions and infrastructure damage. It also occasionally happens with short-lived disruptions where a few ships can be diverted to an alternative port. Cruise lines also redirect cruises to alternative ports of call during a hurricane and, on rare occasions, are forced to switch to a different home port.

Supply Chain Challenges and Implications for Food Security

Supply chain challenges and performance of the freight transportation system have affected the U.S. economy since the beginning of the COVID-19 pandemic. Container ports continue to be burdened by shortages, including intermodal shipping containers and chassis, as the demand for ocean shipping and port services exceeds supply, furthering disruptions throughout the supply chain. In 2021, freight costs increased across all modes with increases as high as 20% and since around 80% of the world's goods are transported by sea, ocean freight costs have skyrocketed (Jain, 2023).

According to the Agricultural Transportation Working Groups (ATWG) the most problematic supply chain issues for the agricultural industry include transportation costs, rising energy costs and challenges obtaining inputs and products for the agricultural sector (Fatka, 2021). However, inadequate labor availability is the largest supply chain constraint. ATWG contends that their members are unable to fill open positions throughout the production, transportation, warehousing, and processing phases of the supply chain which are directly impacting members' ability to meet consumer demands (Fatka, 2021).

Other challenges stem from recent and particularly long periods of drought which have reduced forage, increased irrigation needs, and lowered river levels created extremely low flows in the Mississippi River. Dredging has kept the channel at a depth that enables traffic to continue with full loads. However, reports of light-loading due to the low river level resulting from the drought are increasing. The ability to move freight on the Mississippi River depends on water levels, whether too much due to flooding or too little due to drought. Low water levels in the Lower Mississippi River due to insufficient rainfall have severely hampered barge shipments since fall 2022. Groundings and the need for dredging have closed sections of the river and halted barge movements for intermittent periods. U.S. Coast Guard District 8 (New Orleans) reported a backup of more than 2,000 barges on the Lower Mississippi in early October 2022. Low water also restricts the loads each barge can carry, and the narrower channel restricts the number of barges in a single tow.

Many major barge commodities such as coal, chemicals, and petroleum move at similar volumes year-round. However, grain and other farm products are seasonal and in 2022, southbound grain shipments from the Upper Mississippi through Lock 27, the southernmost lock on the river, have been stalled or delayed on the Lower River. In addition, the river's low water levels have coincided with the peak shipping season for U.S. corn and soybeans, the nation's largest export crops. The October 2022 southbound grain and agricultural product shipments on the Lower Mississippi below Lock and Dam 2720 were predominately soybeans and corn, leaving those major export commodities most vulnerable to the Lower River disruption.

Sixty-five percent (65%) of America's agricultural exports go through Port NOLA. Bulk grains, grain products, and edible oils are exported through the port, however, the dominant product is poultry. Poultry is one of the largest agricultural enterprises in Louisiana, with approximately 380,000 tons of poultry exported per year contributing over $1 billion to the state's economy. Port NOLA will see a significant increase in its import and export capacity through the construction of a $1.8 billion container facility on the Lower Mississippi River. Construction is slated to begin in 2025 and the first berth to open in 2028. At full build-out, LIT will be able to handle 2 million TEUs (20-foot equivalent units) annually, taking advantage of the deeper 50-foot Lower Mississippi River Ship Channel and avoiding height restrictions from Mississippi River bridges further up the river. Poultry export is anticipated to grow to 600,000 metric tons per year.

According to an April 14, 2021, Congressional Research Service (CRS) report, sales of U.S. agricultural products to foreign markets absorb about one-fifth of U.S. agricultural production, contributing notably to the health of the farm economy. Over the years, additional countries have become significant importers of U.S. farm products, and high-value products have come to account for a larger share of U.S. export value. The report also notes that the total value of U.S. agricultural exports has declined since 2014, largely due to lower prices of bulk agricultural commodities, even as export volumes have continued to grow (CRS, 2021). The growth in the value of U.S.

agricultural imports has outpaced the growth in U.S. agricultural exports, contributing to a decline in the U.S. agricultural trade surplus from $16 billion in 2016 to $4 billion in 2020 (CRS, 2021).

The 2018 farm bill established a new priority for U.S. agricultural policy: promoting global food security, defined as "access by any person at any time to food and nutrition that is sufficient for a healthy and productive life." Meanwhile, consumers increasingly demand products that reflect their values. In specific countries, this translates to increased demand for organic food and a growing interest in products certified as having been produced without the use of forced labor or illegally deforested land or produced using sustainable practices. These changing consumer demands are creating new market opportunities for US farmers. Some experts assert that the United States' core advantage in agricultural exports may lie in quality, safety, and other nonprice factors. Communication of these differences to potential foreign buyers via certification schemes may benefit U.S. exports.

3. IMPACTS/BENEFITS OF IMPLEMENTATION

Numerous impacts and benefits were gained from this project. A major outcome is the increased knowledge and understanding of how the location, the impact of climate change and conditions of port infrastructure can function as chokeholds to agricultural trade. Ports are critical infrastructure nodes in the maritime transport network, where agricultural commodities are loaded, unloaded, stored, or transferred to other modes of transport. Port location determines its exposure to climatic hazards, such as sea level rise, storm surges, waves, floods, droughts, and heatwaves. These hazards can damage port infrastructure, disrupt port operations, and increase costs and delays for agricultural trade. For example, ports in low-lying coastal areas are more vulnerable to sea level rise and flooding, while ports in arid regions are more prone to water scarcity and heat stress (Asariotis, 2021). Climate change is expected to increase the frequency and intensity of extreme weather events, as well as the mean sea level, temperature, and precipitation (Asariotis, 2021). These changes can have both direct and indirect impacts on ports and agricultural trade. Direct impacts include physical damage to port infrastructure, increased maintenance and adaptation costs, reduced operational efficiency, and higher risks of disasters and disruptions. Indirect impacts include changes in agricultural production and demand, shifts in trade patterns and routes, and effects on global supply chains and food security (Economist, 2020). The condition of port infrastructure can be chokeholds to agricultural trade affecting global food security, supply chains, and economy. The condition of the infrastructure affects its resilience to climate change and its capacity to handle agricultural trade. Ports with inadequate or outdated infrastructure may face more challenges in coping with the impacts of climate change and meeting the growing demand for agricultural trade (Asariotis, 2021). Ports with modern and adaptive infrastructure may have more opportunities to enhance their performance, competitiveness, and sustainability (UNCTAD, 2011).

According to Bailey and Wellesley (2017), there are 14 chokepoints that are critical to global food security, and 8 of them are coastal ports in major crop-exporting regions, such as the US Gulf Coast, Brazil's Santos and Paranaguá, and Argentina's Rosario. These ports handle more than half of the global soybean exports, and a quarter of the global wheat and maize exports. However, these ports also suffer from inadequate infrastructure, low productivity, and frequent strikes, which can create bottlenecks and increase transport costs (Bailey and Wellesley, 2017). The blocking of the Suez Canal in March 2021 also highlight transport bottlenecks and the exposed the risks and interdependencies of global supply chains.

A second major benefit resulting from this project is the information and analyses that can be used by decision makers in designing smart and sustainable maritime infrastructure. Information and analyses on port infrastructure vulnerability and resilience can be used by decision makers in designing smart and sustainable maritime infrastructure in several ways. These include identifying the most critical and vulnerable ports and terminals that are essential for global food security, supply chains, and economy; assess their exposure levels to various natural and anthropogenic hazards; prioritize their protection and improvement by devising and implementing response and mitigation measures that can prevent, prepare, or adapt to port disruptions, and speed up the recovery of port activities. Information and analysis can also be used to evaluate and compare the costs and benefits of different response and mitigation measures and allocate the necessary resources and responsibilities for their implementation followed by monitoring and reviewing the performance and effectiveness of the implemented measures and identify the gaps and challenges that need to be addressed.

A third benefit is increased student and public awareness of the elements and value of maritime transportation, chokepoints within maritime infrastructure and their impacts and the connections between maritime transport and food security. The result is a more climate conscious society. Climate change is not only a threat to the environment, but also to the US's economy health and security. Information from this project was disseminated through a variety of conferences and presentations including a 2023 dissertation by Jon Vincent Holden on *Vulnerability and Resilience in Maritime Infrastructure in the Deep South and Implications for Agricultural Trade*.

A fourth is benefit is increased engagement of stakeholders in climate change, disaster response and transportation planning and fifth is that the research community is able address key knowledge gaps in the fields of food security, maritime transport networks, disaster resilience, infrastructure development and governance, risk assessment and climate science

4. RECOMMENDATIONS AND CONCLUSIONS

This study supports additional investment into transport facilities as a stimulator of economic growth of a country or region and to safeguard again consequences of climate change such as sea level rise and increased storm frequency and intensity. This study contends that investments into port infrastructure will improve the quality and resilience of port infrastructure which would in turn improve the logistics performance of the country which would bring the greatest benefits to the economy of a country, as it would increase the volume and value of seaborne trade and reduce the trade costs and time. Gains from expanded trade would include improved labor supply, expanded production, diffusion of innovation, competitive pressures, economic restructuring, leading to GDP growth.

Therefore, the conditions of ports as chokeholds to agricultural trade are a significant factor that can influence the global food system, and require more attention and investment from policymakers, stakeholders, and researchers. Improving the efficiency, resilience, and sustainability of ports can enhance the security and stability of agricultural trade, reducing food insecurity and contribute to the development and prosperity of the United States and the entire globe. Some possible solutions include improving the port infrastructure and operations, enhancing the coordination and communication among the port actors, and diversifying the transport modes and routes. However, these solutions may also face technical, financial, or institutional barriers, and may not be sufficient to address the long-term effects of climate change on the water resources and transport systems. Policy approaches could include the development of vulnerability assessment plans or incorporating resilience goals into the standard operations and management programs. More and more, organizations such as seaports have been conducting vulnerability or resilience assessments to identify key areas that need improvement in the face of present and future conditions. However, it is recognized that seaport adaptation measures can be a non-trivial investment of resources.

There is no single approach to climate change adaptation and resilience planning for ports, but an important message for policymakers, industry, and other stakeholders is that “all hands on deck” are needed. In the absence of timely planning and implementation of requisite adaptation measures, the projected impacts on seaports will have broad economic and trade-related repercussions and may severely compromise future trading and development prospects of the US. Given what is at stake and the potential costs of inaction, prevention, and mitigation of climate change impacts on ports – and other key transport infrastructure, should become a major priority as part of sustainable development and climate strategies.

OTHER ACTIVITIES SUPPORTED BY THE PROJECT

Social Connectivity - Reconnecting with Big Rivers: A collaboration between Jackson State University (JSU) and the University of California Berkeley (UCB)

Project Investigators:

- Berneece S. Herbert, PhD., Associate Professor & Chair, Dept. of Urban & Regional Planning, JSU
- G. Mathias Kondolf, PhD., Professor of Environmental Planning, Dept. of Landscape Architecture & Environmental Planning, UC Berkeley

Research & Project Background

Social Connectivity - Reconnecting with Big Rivers

Social connectivity - the communication and movement of people, goods, ideas, and culture along and across rivers

Issue: Public Riverfront Access

- Riverfronts are increasingly valued as public space, but along some large rivers, cities and towns are cut off from their rivers by flood control infrastructure.
- As the riverbanks historically provided important open space and leisure opportunities for people of all walks of life, cutting them off represents a significant impact on recreational opportunities for many in society, notably disadvantaged residents.

Social Connectivity - Reconnecting with Big Rivers

- Historically, the most important longitudinal connectivity function of rivers was their role as major transport routes.
- The simplification of formerly complex, irregular banks and beds, into straight, uniform shipping channels has resulted in a loss of lateral and vertical connectivity, notably uses such as fishing, washing clothes, water supply, swimming and other recreation

Collaboration - Student Exchange

- ✓ Students from JSU and UCB assessed social connectivity along sites on the Sacramento and Mississippi Rivers
- ✓ Focus on three types of social connectivity –longitudinal, lateral, and vertical connectivity:
    - access to rivers as they pass through cities
    - the relationships between these rivers and city dwellers.
- ✓ Make recommendations for improving public access in light of current land use, flood control constraints, and evolving opportunities.
- ✓ Mississippi trip also had a flooding component

Project Objectives:

- Assess social connectivity along the Mississippi River in Vicksburg, and the Pearl River in Jackson
- Tour the Ross Barnette Reservoir and examine flood issues in Jackson MS

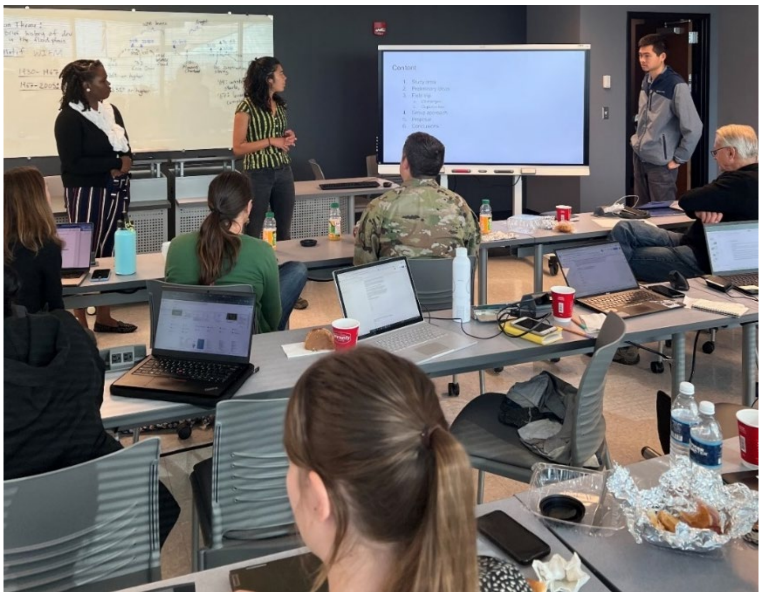
Team:

- 12 students
- 1 researcher
- 2 Army Corps of Engineers
- 3 faculty members

Team 1 Overview: River Access in Vicksburg, MS on the Mississippi River

Challenges:

- Limited access (not walkable, no bicycle infrastructure)
- Erosion
- Limited funding
- Flooding

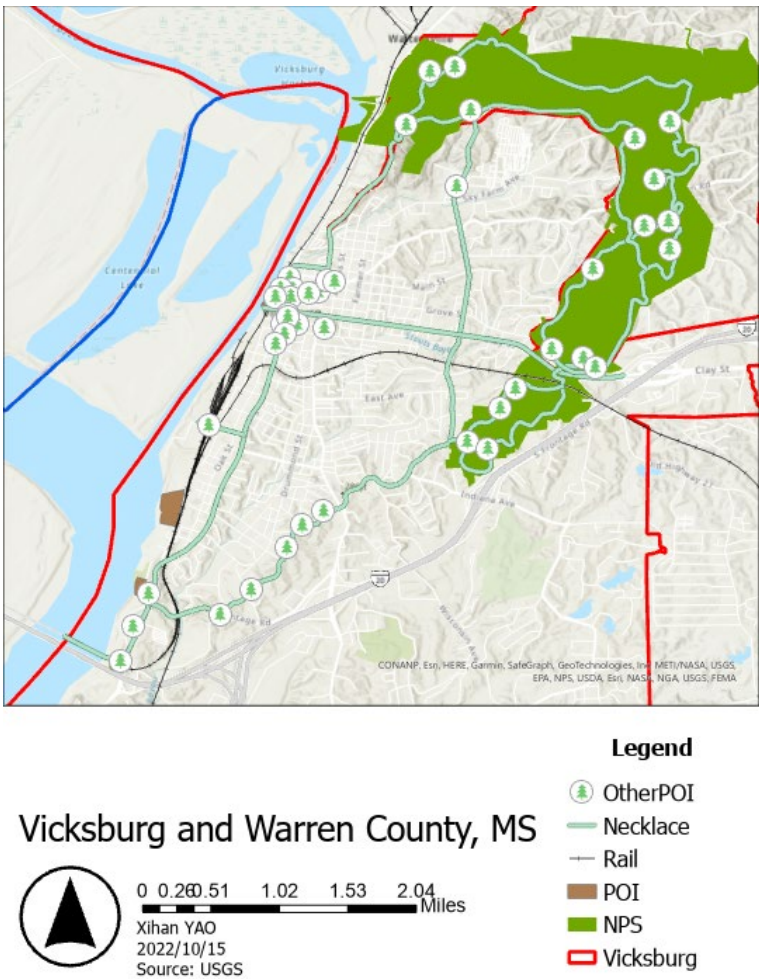


Team 1 Recommendations

1. Build on opportunities that are already in Vicksburg
   - Inclusive projects
   - Stakeholders
   - Best practices
   - New long-lasting partnerships with stakeholders and community members
2. Connectivity between public open spaces
3. Connection people-river: visual and physical
4. Offer options for different users:
   - Views of the Mississippi, paddling options for the most adventurous.
   - bike/pedestrian/bus/car
   - Recreation + history + ecology + art

Team 1 Proposal: The Necklace of Vicksburg

- Design a Multi-use trail connecting museums, parks, riverfront access areas and hilltop viewpoints.
- Integrate National Military Park, Washington Street, Clay Street, Confederal Avenue to connect attractions and balance the city development.
- River accessibility:
- Riverfront parks, boat launching, Fairground St Bridge Passing



Team 2: River Access in Jackson, MS on the Pearl River

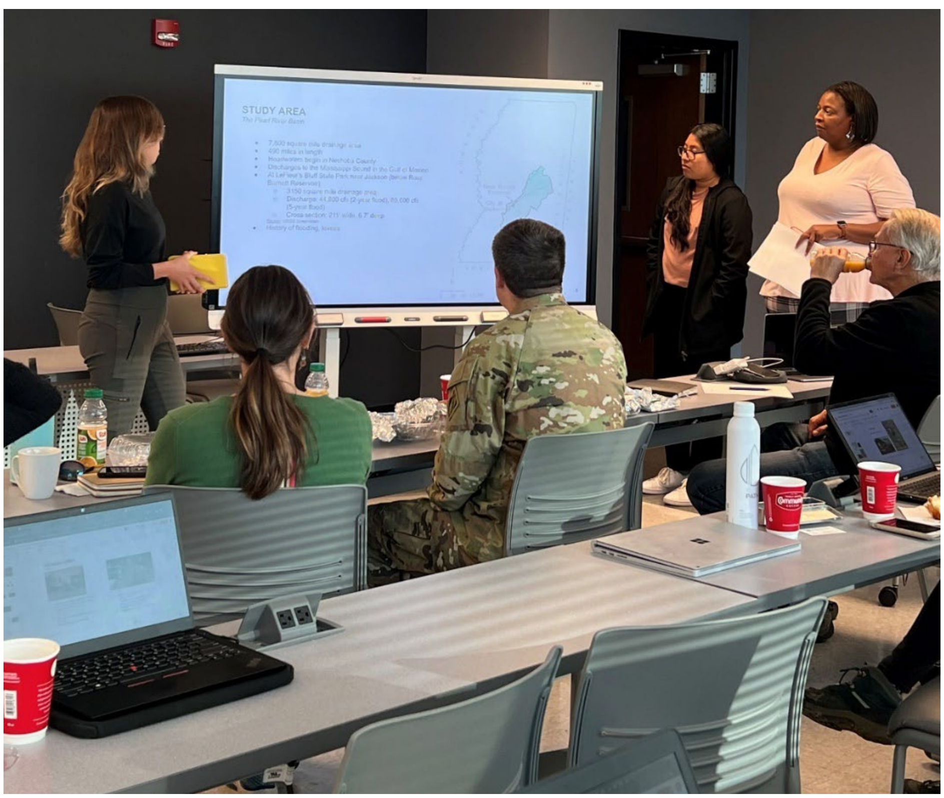
STUDY AREA

The Pearl River Basin

- 7,800 square mile drainage area
- 490 miles in length
- Headwaters begin in Neshoba County
- Discharges to the Mississippi Sound in the Gulf of Mexico
- At LeFleur's Bluff State Park near Jackson (below Ross Barnett Reservoir):
    - 3150 square mile drainage area
    - Discharge: 44,800 cfs (2-year flood), 80,600 cfs (5-year flood)
    - Cross section: 211' wide, 6.7' deep

<u>Source</u>*: USGS Streamstats*

- History of flooding, levees



FIELDWORK & FINDINGS: *Pearl River Accessibility*

PROPOSED INTERVENTIONS

Town Creek at Farish Road

- Creek restoration, removal of invasives, replacements with native plants and trees, signage
- Public access along the creek, docks and platforms to see the river

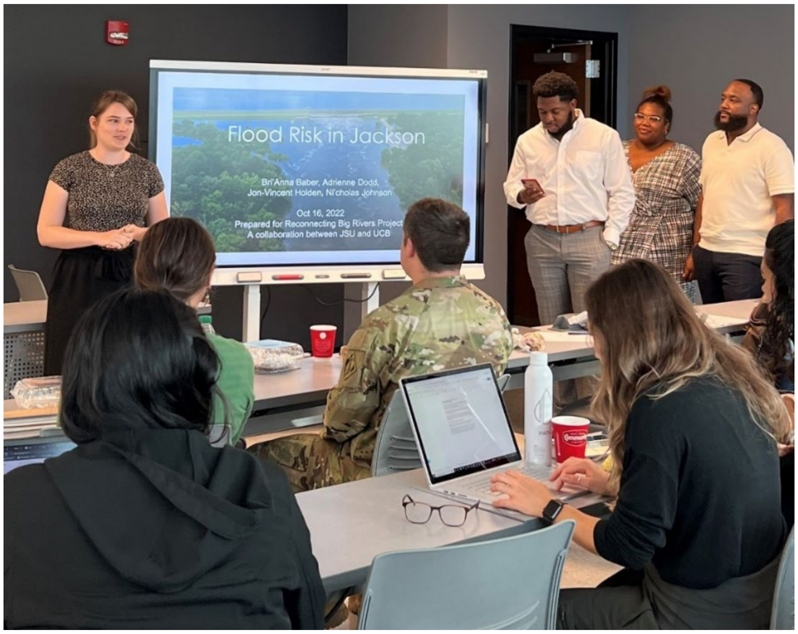
Example of urban stream restoration at Marsh Creek in Oakley, California, by Restoration Design Group

Example of platform pathway system or dock for lateral connectivity

Hiking and biking trail along the South Platte River in Denver, Colorado

- Regional Collaboration - Key Partnerships
  - Mississippi Department of Fish and Wildlife
  - City of Jackson
  - Mississippi Rural Water Association
- Funding and Maintenance
  - City of Jackson; Mayor of Jackson to obtain grants for streetscape and cleanups, improvements, and help address access issues
  - Department of Public Works
  - Funding, Streetscape, and Waterway Improvements: State and Federal Agencies
  - In the future, local groups, community organizations, volunteers

Team 3: Flood in Jackson, MS on the Pearl River



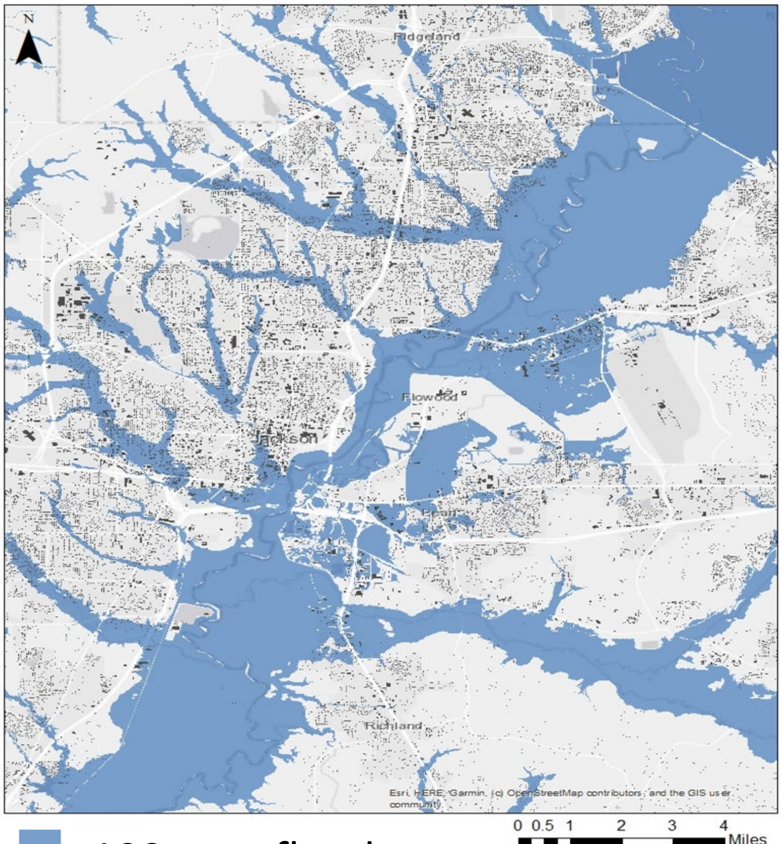
Challenges:

- The City of Jackson does not have a Local Hazard Mitigation Plan, or a plan focused on flood risk, mitigation, response, and recovery.
- Plans that exist are regional and the City is not the major stakeholder or decision maker.
- Little funding for maintaining infrastructure and reducing flood risk.
- Uneven distribution of flood risks with minority communities bearing greatest risks.
- Residents are concerned about corruption and apathy on the part of local and state government to help with flood risk.
- Repeated flooding leads to high cost
- Flood Insurance increased from $375/year in 2004 to $2,700/year in 2022.

Flooding In Jackson

Flooding in Jackson is creek based. As the Pearl River water level rises, the tributaries start to get backed up, overflowing into their floodplain and inundating neighborhoods.

When looking at risk and mitigation of hazards, it is especially important to research racial inequity in the distribution of flood risk and flood mitigation, ask why distribution is that way, and how it can be addressed (Chakraborty et al., 2014; Lieberman-Cribbin et al., 2021).



100-year flood zone (FIRM: AE)

Ross Barnett Reservoir

The Pearl River Valley Water Supply District

- 35,000 acres of reservoir, 17,000 acres of land housing 12,900 people
- Not designed to control floods, but water level kept high for water supply, aesthetics, and recreational purposes.
- Summer water level: 297.5ft
- Winter water level: 296ft

Team 3 Alternative Mitigation Options

Reduce Exposure

- Stop new housing development in the floodplain
- Focus on creating new housing development in non-hazard areas

Reduce Housing Vulnerability

- Provide funding opportunities for residents to flood-proof existing housing

Make Room for Water

- Widen the Pearl River's active channel
- Install flood walls along creeks, paired with river restoration and river access projects as desired by community members
- Reduce the reservoir's normal operating water level

Team 3 Future Work

Distributional Injustice

- Is there inequity in exposure to flood risk among different racial and income groups?
- Is there inequity in investment in flood mitigation features and resources?

Procedural Injustice

- Is there inequity in who is included in decision-making processes?
- Is there inequity in what individuals and communities gain access to aid?

Mitigation

What are feasible ways to reduce the risk of inundation and water backup in tributaries of the Pearl River? What funding pools can communities in Jackson access to reduce risk?

Final Product Outcome:

Green Heart of the Pearl is the final report from the JSU/UCB Student Exchange Project. It can be found at: http://riverlab.berkeley.edu/reconnecting-with-big-rivers/

CONFERENCES & OTHER ACTIVITIES

- AL/MS American Planning Association Conference, Orange Beach Alabama, Oct 24 – 26 Paper: Vulnerability & Resiliency Dimensions of Maritime Transportation Infrastructure to Climate Change in the Deep South; Berneece Herbert, Presenter
- Council of Educators in Landscape Architecture, San Antonio, TX, March 16-18, 2023; Paper presented on Human & Rivers: Challenges to Public Access & Equitable Flood Risk Management (focus on the Sacramento (CA) & Mississippi and Pearl Rivers (MS); B. Herbert (JSU) and M. Kondolf (UC Berkeley)
- C40 Master Class on Climate & Equity. Green Infrastructure for Heat Mitigation; Feb 1 - 3 2023 Philadelphia
- Urban Water Crisis in the City of Jackson, MS; B. Herbert; 2023 Planning Colloquium; University of Illinois, Urbana-Champaign; March 3
- Partnerships with Caltrans with Special Topics
- Dissertation 2023: Vulnerability and Resilience in Maritime Infrastructure in the Deep South and Implications for Agricultural Trade. Author: Jon Vincent Holden
- Faculty and students to attend 4th annual Research-to-Practice Transit Symposium on October 24-26 sponsored by CalTRANS
- URP 550/770: Special Topics is a joint transportation related course offered by DURP in conjunction with Caltrans Division of Rail and Mass Transportation (DRMT) in California. The MOU facilitates the establishment of channels of communication that permit the creation and interchange of information, as well as scientific, technical, and departmental collaboration in the areas of rail and mass transit during an 8 week course during the summer sessions. Due to the success of this course, the department is currently developing a transportation concentration for its graduate programs. URP 550/770 Special Topics: Summer 2023; topic covered include Zero-emissions and hydrogen trans (ZEHTRANS); Human Transit: How Clearer Thinking about Public Transit Can Enrich Our Communities and Our Lives; Bicycle/Race: Transportation, Culture, & Resistance.
- Development of a prospectus for a new undergraduate program in environmental planning and urban sustainability that will enable students to select courses on transportation planning and urban design.

Collaborators

- Robert W. Whalin- Professor College of Science, Engineering and Technology, Jackson State University, Jackson, Mississippi
- Sharon Gordon - Local Programs Engineer, Federal Highway Administration, Jackson MS
- Shundreaka Givan, Deputy Division Administrator, South Carolina, Federal Highway Administration
- Emily Erickson (Univ. of Warick, England)
- Chloe Dotson (City of Jackson MS)
- Dominika Parry (Climate NGO)
- Jürgen Hackl (Princeton University)
- Stephen Barnes (University of Louisiana)
- Jae-Young Ko (JSU)
- Rebecca A. Efroymson (Oak Ridge National Laboratory)

Partnerships involve research projects and new grant applications with Drs Hackl, Barnes and Ko.

References

Across Logistics. (September 23, 2022). Maritime transportation. Advantages and disadvantages. Maritime transportation. Advantages and disadvantages (acrosslogistics.com).

Agricultural Marketing Service. (July 2009). Grain Transportation Report https://apps.ams.usda.gov/SearchReports/Documents/stelprdc5077874.pdf.

American Farm Bureau Federation (n.d.) Infrastructure White Paper. https://www.kyfb.com/federation/public-affairs/national/farm-labor-resources/wrda-infrastructure/.

American Society of Civil Engineers. 2017 Infrastructure Report Card: A Comprehensive Assessment of America's Infrastructure. https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/2017-Infrastructure-Report-Card.pdf.

Asariotis, R., and Benamara, H. (Eds.). (2012). Maritime transport and climate change challenge. Routledge.

Asariotis, R. (June 4, 2021). Climate change impacts on seaports: A growing threat to sustainable trade and development. UNTAD Article No. 75 [UNCTAD Transport and Trade Facilitation Newsletter. https://unctad.org/news/climate-change-impacts-seaports-growing-threat-sustainable-trade-and-development.

Blanton, B. (February 2, 2017). The Importance of Transportation to Agriculture presentation. https://www.ams.usda.gov/reports/importance-transportation-agriculture

Blue Oceans Magazine. (February 2, 2020). Advantages of Maritime transport. https://blueoceanmag.com/advantages-of-maritime-shipping/

Bureau of Transportation Statistics. (January 13, 2023). 2023 Port Performance Freight Statistics Program: Annual Report to Congress. https://www.bts.gov/newsroom/2023-port-performance-freight-statistics-program-annual-report-congress.

Congressional Research Service U.S. Agricultural Export Programs: Background and Issues April 14, 2021 https://crsreports.congress.gov/product/pdf/R/R46760

Easa, S. El-Rabbany A. and El Halim A.O. (2006). Education and training strategies for promoting marine transportation. Conference Proceedings 3rd International Conference on Inland Water Transport. Luxor, Egypt. https://www.researchgate.net/publication/273694536_Education_and_training_strategies_for_promoting_marine_transportation

Economist. (September 12, 2020). Ports are highly exposed to climate change and often ill-prepared. https://www.economist.com/finance-and-economics/2020/09/12/ports-are-highly-exposed-to-climate-change-and-often-ill-prepared.

Energy Infrastructure (n.d.) State of Maritime: Current State of U.S. Maritime Infrastructure. https://www.energyinfrastructure.org/maritime/state-of-maritime.

Fatka, J. (October 26, 2021). Supply chain issues hitting all segments of ag. https://www.farmprogress.com/farm-operations/supply-chain-issues-hitting-all-segments-of-ag

Improving the U.S. Marine Transportation System. (n.d.). https://www.maritime.dot.gov/outreach/maritime-transportation-system-mts/maritime-transportation-system-mts.

Jain, A. (January 16, 2023). Supply chain challenges in 2023 that need your immediate attention. https://www.gocomet.com/blog/supply-chain-challenges-in-2023/.

Margolis, J. (November 28, 2019). The Mississippi: Pushed to the brink. https://theworld.org/stories/2019-09-03/mississippi-pushed-brink.

Bailey, R and Wellesley, L. (June 2017). Chokepoints and Vulnerabilities in Global Food Trade. https://www.chathamhouse.org/2017/06/chokepoints-and-vulnerabilities-global-food-trade.

Nicholls, R. et al. 2008. Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates, OECD Environment Working Papers, No. 1, OECD Publishing, Paris.

Nipa, T. J. and Kermanshachi, S. (2019). Identification of the Resilience Dimensions and Determination of Their Relationships in Critical Transportation Infrastructure. ASCE Construction Research Congress (CRC). Doi.org/10.1061/9780784482858.070.

Organisation for Economic Co-operation and Development (OECD) and United Nations Food and Agriculture Organization (FAO), "OECD-FAO Agricultural Outlook," OECD Agriculture Statistics, 2020, http://dx.doi.org/10.1787/agr-outl-data-en. Figures for 2020-2029 are OECD projections. U.S. Agricultural Export.

Price, C. (February 1, 2018). U.S. Army Corps of Engineers' Plan to Deepen the Mississippi River to 50 Feet. https://www.bizneworleans.com/u-s-army-corps-of-engineers-plan-to-deepen-the-mississippi-river-to-50-feet/

Pudyastuti, S and Nugraha, N (June 26, 2018). Climate change risks to infrastructures: A general perspective. AIP Conference Proceedings 1977. doi.org/10.1063/1.5043000.

USEPA (n.d.). Climate Change Impacts on Transportation. https://www.epa.gov/climateimpacts/climate-change-impacts-transportation.

USEPA. (June 26, 2023). Ports Primer:2.1 The Role of Ports https://www.epa.gov/community-port-collaboration/ports-primer-21-role-ports#:~:text=The%20Intermodal%20Transportation%20System%20connects,local%20communities%20and%20worldwide%20markets.

Regmi. A. (April 14, 2021). U.S. Agricultural Export Programs: Background and Issues. https://www.everycrsreport.com/reports/R46760.html.

U.S. Department of Transportation (2020), Goals and Objectives for a Stronger Maritime Nation: A Report to Congress, Washington, D.C., 17 p.

USDA's Grain Inspection, Packers and Stockyard Administration, https://www.usda.gov/sites/default/files/documents/17-09-GIPSA.pdf.

United States Navy (n.d.). Sealift Program. https://www.msc.usff.navy.mil/Ships/Sealift-Program-PM5/.

UNCTAD. (September 10, 2011). Climate change impacts on ports and trade: The need to adapt. https://unctad.org/news/climate-change-impacts-ports-and-trade-need-adapt.

UNCTAD Research Paper No. 18. Port Industry Survey on Climate Change Impacts and Adaptation. https://unctad.org/publication/port-industry-survey-climate-change-impacts-and-adaptation.

The Economist. (September 12, 2020). Ports are highly exposed to climate change and often ill-prepared. https://www.economist.com/finance-and-economics/2020/09/12/ports-are-highly-exposed-to-climate-change-and-often-ill-prepared.

Vogelson, S. (June 15, 2021). For Virginia, adapting to sea level rise starts with choosing a curve. https://www.virginiamercury.com/2021/06/15/for-virginia-adapting-to-sea-level-rise-starts-with-choosing-a-curve/.