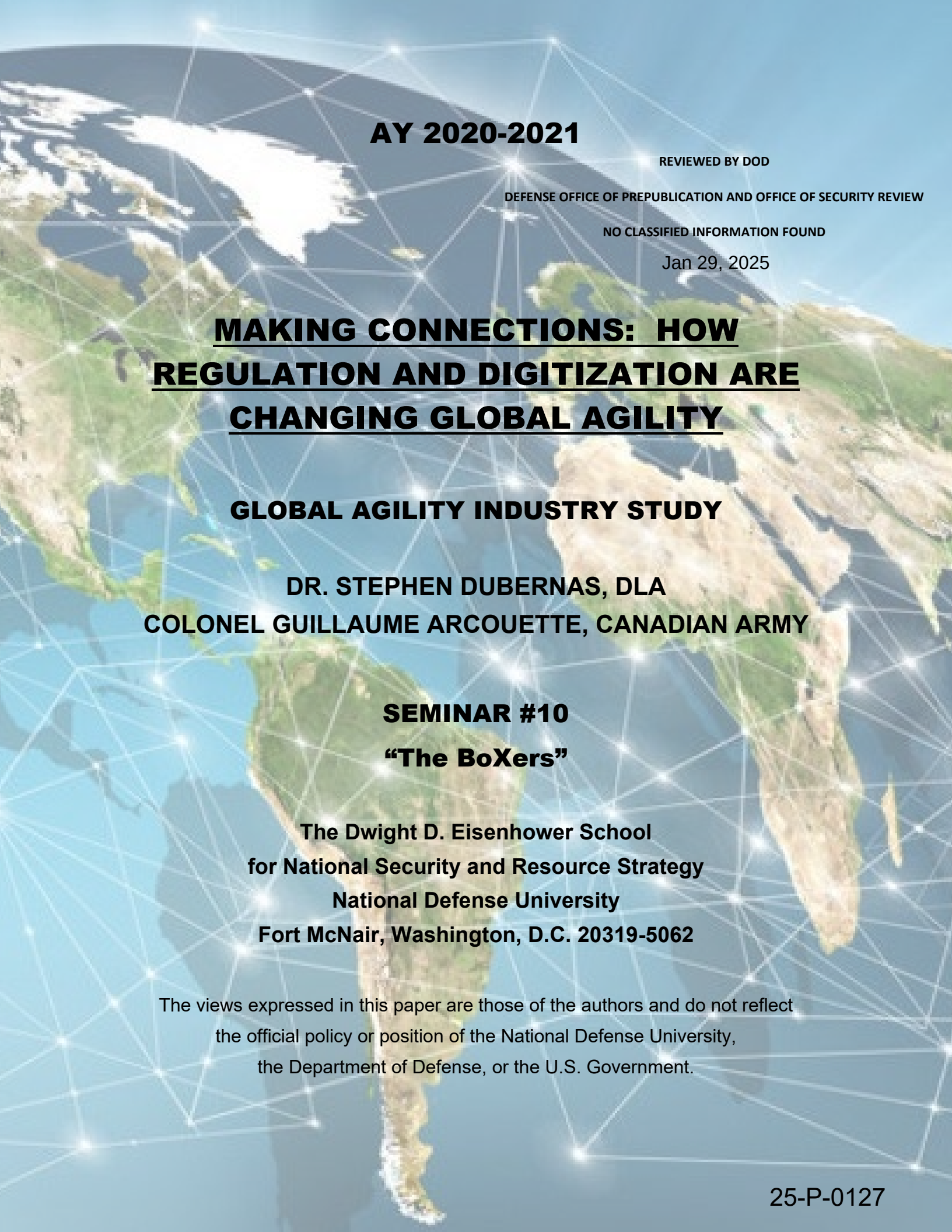

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MAKING CONNECTIONS: HOW REGULATION AND DIGITIZATION ARE CHANGING GLOBAL AGILITY

GLOBAL AGILITY INDUSTRY STUDY

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Abstract

Global agility is a complex adaptive system that leverages an interlocking network of industries to enable the timely, efficient, and resilient planning, transportation, storage, and distribution of goods within a nation and around the world, thereby enabling a healthy domestic industrial base and competitive advantage in international trade.[a]

Global agility enables power projection through economic growth and mobilization. However, several broad challenges, including ossifying industries, an outdated regulatory environment, resistant human capital, and aging infrastructure raise concerns about the ability of this sector to support national security requirements. For the U.S. to effectively compete with increasingly aggressive Chinese policies and tactics in a dynamic national security environment, we recommend several policy initiatives in an era of great power competition.

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[a] Cover art from iStock, "Networked Globe," World University Rankings (Times Higher Education, January 14, 2016), https://www.timeshighereducation.com/features/200-most-international-universities-world-2016.

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*Team Global Agility did not participate in all planned domestic or any international field studies due to COVID-19 travel restrictions.

Global agility is an interlocking network of logistics industries that enables planning, transportation, storage, and distribution of goods.[b]

[b] Image source: WMRE Staff, "Global Agility System Elements," Wealth Management Real Estate, April 30, 2019, https://www.wealthmanagement.com/industrial/top-global-logistics-hubs-prime-yield.

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Executive Summary

The global agility system links buyers and sellers through a host of transportation and distribution options, including deep-water shipping, inland waterway transportation, ports and harbors, warehousing, railways, trucking, air freight, and space logistics. Since the Industrial Revolution, the U.S. set the standard in global logistics, distribution, and supply chain management. However, today many global agility industries are mature, resistant to change, lack pressure from the competitive forces that prod firms to innovate, and stagnant due to government policies. Common challenges include ossifying industries, outdated regulatory environment, resistant workforce, and aging infrastructure.

While the reemergence of great power competition illuminates the need for balance among of all instruments of national power, the global agility network primarily fortifies the links and nodes that connect the military and economic instruments. To this point, the U.S. has enjoyed a large lead in both domains, but resurgent Russia and revisionist China challenge U.S. prosperity and security by staking claims in logistics industries traditionally dominated by American firms. The U.S. must sustain its lead in the industries it currently dominates, remove barriers in the industries in which it is falling behind, and provide incentives for industry to innovate across the global agility enterprise through the following policy recommendations:

Deep-water

1. Modify the Jones Act to allow U.S. shipping firms to purchase foreign-built vessels.
2. Permit Maritime Security Program carriers to use non-U.S.-flagged vessels domestically.
3. Establish the U.S. Merchant Marine as the ninth federal uniformed service.

Inland Waterways

1. Repeal or amend the Jones and Foreign Dredge Acts.
2. Reevaluate distribution of the Inland Waterways and Harbor Maintenance Trust Funds.
3. Restructure inland waterway industry funding via demand-risk public-private partnerships.

Ports and Harbors

1. Expand U.S. dredging fleet capacity.
2. Link ports and harbors with national security.
3. Establish incentives for increased private investment in port modernization and maintenance.
4. Explore methods to modernize facilities to combat rising sea-levels.

Railways

1. Remove regulatory barriers to industry innovations in safety, efficiency, and maintenance.
2. Restrict government-sponsored rail contracts that subcontract to foreign firms.
3. Establish robust standards for cyber and data integrity.

Trucking

1. Create a national apprenticeship program to increase the driver pool for the trucking industry.
2. Modify the Highway Tax Fund to support comprehensive road and bridge improvements.

Air Freight

1. Implement a new Transportation Security Administration security plan that balances risk against efficiency.
2. Continue technology development for the U.S. air cargo industry to augment the Civil Reserve Air Fleet.

Warehousing

1. Model industry best-practices in warehouse location and design, especially for mobilization.
2. Develop a nationwide data exchange platform to standardize across government and industry.
3. Retrofit existing warehouse space to promote downsizing, sub-leasing, or consolidation.

Space

1. Quantify and charge commercial launch customers for holistic launch services.
2. Shift the focus of the hypersonic strategy from offensive long-range artillery to logistics.
3. Negotiate an orbital use-fee treaty among space-faring nations to mitigate space debris.

Map depicting all ships and all routes in global merchant fleet.[c]

[c] Image source: Kiln and University College London, "Ship Map," Business Insider, December 23, 2017, https://www.businessinsider.com/map-of-global-shipping-interactive-2017-12.

What is Global Agility?

"You will not find it difficult to prove that battles, campaigns, and even wars have been won or lost primarily because of logistics."
-- Dwight D. Eisenhower

Trading to improve economic outcomes is a timeless concept. Since the first cavemen bartered food for firewood, thereby increasing each other's wealth and well-being, humans have recognized the welfare gains enabled by specialization and trade. Later, Asian and European merchants exchanged silk and spices across the intercontinental trade route known as the Silk Road, and globalization was born. Since the turn of the 21st century, trade has accounted for over half of global gross domestic product (GDP), improving standards of living across the world and lifting hundreds of millions out of poverty. [1]

As trade begets wealth, wealth builds national prosperity, and prosperity amplifies diplomatic, information, military, and economic power. Throughout history, nations (including the U.S.) vied for economic and military hegemony by protecting their wealth-generating trade routes. Today, the U.S.'s position as *de facto* leader of the rules-based international order is intrinsically linked to free and open international markets coupled with the inherent ability to mobilize domestic and allied industry in case of a national security emergency. Moreover, U.S. military power projection depends on continued unfettered freedom of movement and long-term sustainment of global lines of communication. As then-General Dwight D. Eisenhower and countless others have said, "logistics wins wars." Future success in great power competition requires a robust, resilient, unencumbered, efficient, and agile global logistics system.

Therefore, we define "global agility" as a complex adaptive system that leverages an interlocking network of industries to enable the timely, efficient, and resilient planning, transportation, storage, and distribution of goods within a nation and around the world, thereby enabling a healthy domestic industrial base and competitive advantage in international trade. Put simply, it is the movement of all goods and services across the nation and throughout the world via thousands of access points, or logistics nodes, to connect customers and suppliers as efficiently as possible. In global agility, the whole is greater than the sum of the parts.

Global Agility System Elements

"Victory is the beautiful, bright-colored flower. Transport is the stem without which it could never have blossomed."
--Winston Churchill

Serving as economic "connective tissue," the global agility system links buyers and sellers through a host of transportation and distribution options, including deep-water shipping, inland waterway transportation, ports and harbors, warehousing, railways, trucking, air freight, and space logistics.

Deep-water shipping

Oceans encompass 70 percent of the Earth's surface. Little surprise, then, that 90 percent of goods exchanged in the world travel via deep-water shipping. Deep-water shipping is part of the international maritime transportation system comprised of five groups: (1) vessel operations, (2) shipbuilding and maritime engineering, (3) marine resources, including oil, gas, and minerals, (4) fisheries, and (5) tourism and services. While the U.S. operates only 0.4 percent of the world fleet, the U.S. economy alone accounts for nearly a quarter of global marine freight value, and U.S. Transportation Command (TRANSCOM) estimates the Department of Defense (DoD) would transport 90 percent of military cargo via sealift during a major overseas conflict. To meet peacetime and contingency sealift needs, the U.S. will need to address capacity shortfalls, revise archaic policies, and deal with workforce challenges.

Inland waterways

Often overlooked but vitally important to the efficient transportation of commodities from coast-to-coast, the inland waterway shipping industry includes the infrastructure, personnel, and vessels that carry waterborne cargo along nearly 12 thousand miles of the nation's lakes, rivers, and man-made inland waterways via more than 200 navigational locks. Over 500 million tons of commodities, including petroleum, farm inputs, corn, and other food products travel across U.S. waterways, yet the industry faces extraordinary economic pressures from alternative forms of transportation such as rail and trucking. To remain viable, policymakers will need to repair aging infrastructure, increase dredging, and shift some economic burden to private industry.

Ports and harbors

Ports connect the maritime and land domains. Ports contain the infrastructure, equipment, personnel, and intermodal transportation nodes that enable the storage, handling, and onward movement of maritime cargo. Meanwhile, harbors are geographic configurations on a coastline where vessels may find shelter from rough water. If a harbor is large enough, it could house a port. Increased demand for imported goods, work stoppages, and Coronavirus restrictions created congestion at east- and west-coast ports, highlighting how critical ports and harbors are to global agility. To wit, California ports alone account for one-third of all U.S. imports, yet in April 2021 nearly two dozen cargo ships were awaiting their turn to dock.[2] Acknowledging the important links between ports and national security, policymakers should explore pathways that better enable private and state-run port facilities to modernize in order to improve U.S. trade and mobilization capacity.

Warehousing

The warehouse industry is undoubtedly complex, and over time has grown to include not only storage, but also distribution, supply chain management, and third-party logistics functions. Growth in global trade and e-commerce has resulted in severe warehouse space shortages. Plato once wrote, "[o]ur need will be the real creator." In the spirit of the great philosopher, the warehousing industry responded to global agility demands by innovating to improve warehouse

location and design. Truly, the warehousing industry shines as a model of an iterative, technology-driven, cost-effective, and efficient logistics platform. "Smart warehouses" support economic growth and military mobilization and set a standard for the rest of the global agility system elements to emulate.

Railways

The U.S. freight railway network is considered the most extensive, safest, and cost-effective freight system in the world. It moves more than one-quarter of the nation's freight, serving nearly every industrial, wholesale, retail, and resource-based sector of the economy. It connects ports to urban and rural areas, joins military bases to key logistical nodes, links U.S. consumers and producers to international markets, and serves as a "pressure-release valve" for America's overloaded highway system. Despite freight rail infrastructure being entirely privately funded, the industry is still subject to a high level of regulation. To remain competitive, the U.S. will need to remove stifling regulations, protect domestic industry from Chinese interlopers, and invest in cybersecurity.

Trucking

Often undervalued and unglamorous, commercial trucks have moved literally every commodity, agricultural foodstuff, and consumer good ever produced from coast-to-coast since the turn of the 20th century. Moving nearly 75 percent of all freight tonnage in the U.S., if trucking were a nation, it would have ranked 33rd-largest by GDP in 2018. While a critical driver of U.S. economic health, the trucking industry has nevertheless faced severe driver shortfalls and infrastructure challenges, delaying deliveries and increasing costs to operate. To stop the proverbial bleeding, the U.S. should incentivize trucking careers and fund road and bridge improvements.

Air freight

Like its ground-based analogs, air freight is no more than movement of goods from one location to another using an aircraft. Unlike ground-based inland distribution, air freight is characterized first by speed, enabling rapid response to emergency transportation needs. Moving both people and cargo, air freight is a driving force behind regional and international connection, which entails economic, military, political, and social implications. More than any other global agility industry, air freight highlights the risk-vs-security tradeoff: comprehensive physical checks of all air cargo cost precious time and money, perhaps negating air's speed advantage. To maintain U.S. air freight supremacy, policymakers must carefully balance security costs and benefits.

Space logistics

Space logistics, a nascent industry among established global agility elements, is ill-defined. The U.S. Space Force (USSF) recognizes space mobility and logistics as key to cross-domain power projection, yet the majority of current and projected space activity is for peaceful economic ventures. Launch providers, analogous to long-haul truckers for space, supply the

critical means of transportation for both national security and private commercial customers to move goods and people from terrestrial to outer space locations. America's benevolent stewardship of space on behalf of the peace-loving nations of the world depends on our domination of the space domain. To remain the best in the world at space, the U.S. should assign "ownership" of space launch infrastructure and further develop space technology.

Global agility industries make domestic and international trade possible.[d]

Global Agility Challenges

"Accelerate change or lose." – General CQ Brown
"The only one who likes change is a wet baby." – Mark Twain

Since the Industrial Revolution, the U.S. set the standard in global logistics, distribution, and supply chain management. In fact, America's continued economic and military prowess rests on our legacy of strength in global agility. However, many global agility industries are mature, resistant to change, lack pressure from the competitive forces that prod firms to innovate, and stagnant due to policies we have imposed on ourselves. Common challenges include:

Ossifying industries

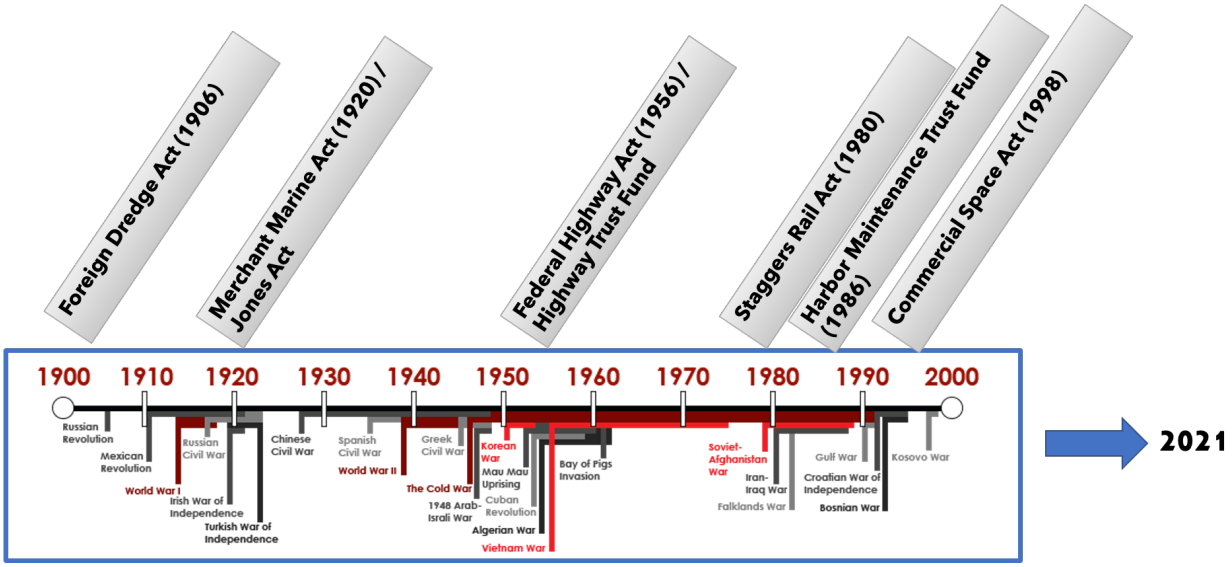
Mature industries benefiting from protectionist policies face little incentive to change. For instance, the deep-water shipping fleet is old and static, the dredging fleet is almost entirely

[d] Image source: Patrice Johnson and Seminar Ten, "Global Agility and the Domestic Economy," Global Agility Industry Analysis, May 21, 2021.

dependent on foreign designs, and the inland waterways market is dominated by three major firms. Stagnation within the industry permits foreign competitors to gain traction.

Outdated regulatory environment

Inextricably linked to ossification, many global agility system elements are "protected" by legislation intended to improve economic outcomes for narrowly defined segments of the industry. The Jones and Foreign Dredge Acts offer textbook examples of harmful legislation that benefits domestic special interests at the expense of national competitiveness in deep-water shipping and inland waterways. Railways, too, suffer from complying with onerous, outdated regulations, precluding the implementation of safety, efficiency, and maintenance improvements.



Legislation and regulations originally intended to stimulate industry or protect American interests now hold back the global agility of the U.S.[e]

Workforce challenges

Several industries struggle to recruit and train employees who are simultaneously willing and able to work. The trucker lifestyle, an old merchant marine, and ancient railroad technology render these industries less attractive to new hires. The more innovative among global agility elements are turning to automation to solve some of their workforce challenges, but unions in key industries continue to resist change.

[e] Image source: Seminar Ten, "Legislation Timeline," Making Connections: How Regulation and Digitization Are Changing Global Agility, May 21, 2021.

Aging infrastructure

The U.S. merchant fleet is in dire need of retrofit, inoperable inland waterways locks delay waterborne shipments, rail infrastructure is expensive to maintain, and space launch infrastructure is insufficient to meet commercial demand. Additionally, the U.S. suffers from more general infrastructure problems that cut across multiple industries, including roads, bridges, the electrical grid, and cyber networks. While many pieces of global agility infrastructure have designated mechanisms to fund their upkeep and expansion, supporting industries may lack the capacity to conduct construction and maintenance, or these funds may be spread across too many projects to be effective.

Eagle, Bear, or Tiger? Global Agility and Great Power Competition

"The line between disorder and order lies in logistics."
-- Sun Tzu

While the reemergence of great power competition illuminates the need for balance among all instruments of national power, the global agility network primarily fortifies the links and nodes that connect the military and economic instruments. To this point, the U.S. has enjoyed a large lead in both domains, but resurgent Russia and revisionist China challenge U.S. prosperity and security by staking claims in logistics industries traditionally dominated by American industry. Russia, while provocative, meddlesome, and a general nuisance in space logistics and cyber security, is hardly coordinated or wealthy enough to directly challenge U.S. dominance of global distribution networks. On the other hand, China is the pacing threat for nearly all other elements of global agility. Especially in the maritime domain, China's global investments and wolf-warrior diplomacy tactics threaten America's influence and access to deep-water shipping lanes, shipbuilding, and ports. Likewise, by applying maritime lessons learned to broader transportation networks, China intends to create advantages for itself in the air freight and rail industries.

A strong national defense protects a healthy economy and economic wealth buys better defense. In an era of great power competition, the U.S. must sustain its lead in the industries it currently dominates, remove barriers in the industries in which it is falling behind, and provide incentives for industry to invest and innovate across the global agility enterprise.

The Bottom Line: Recommendations

"Nothing is less productive than to make more efficient what should not be done at all."
--Peter Drucker

Students in the Global Agility Industry Study cohort benefitted from hearing directly from industry titans spanning the entire logistics and supply chain management spectrum. Additionally, independent research, frank and lively discourse, and Socratic "processing

sessions" generated policy insights for specific areas where government-industry partnerships might strengthen the global agility system. The outcome of research, writing, and discussion culminates in the following policy recommendations:

Deep-water shipping

1. Modify the Jones Act to allow U.S. shipping firms to purchase less expensive foreign-built commercial vessels, increasing the number of ships in the domestic fleet and dramatically reducing shipping costs.

2. Expand the Maritime Security Program (MSP) to permit participating carriers to use their non-U.S.-flagged vessels for designated domestic routes in exchange for greater and assured access to those ships in a time of national crisis.

3. Establish the U.S. Merchant Marine as the ninth federal uniformed service, with an active duty and reserve component, to encourage more people to become and remain mariners.

Inland waterways

1. Repeal or amend the Jones and Foreign Dredge Acts to encourage competition with foreign-owned dredging and inland waterway shipping firms.

2. Reevaluate the Inland Waterways Trust Fund (IWTF) and Harbor Maintenance Trust Fund (HMTF) distribution, focusing on funding projects proportionate to network area use and overall network.

3. Restructure inland waterway industry funding methods via demand-risk public-private partnerships.

Ports and harbors

1. Expand U.S. dredging fleet capacity to make full and timely use of the HMTF.

2. Link ports and harbors with national security to provide greater weight to requests for resources by port operators.

3. Establish incentives, via heightened consideration for grants, for increased private investment in port modernization and maintenance.

4. Explore methods to help port operators modernize facilities to combat rising sea-levels.

Railways

1. Review existing and proposed rail safety regulations in order to identify and remove barriers to industry innovations in safety, efficiency, and maintenance.

2. Implement restrictions on government-sponsored rail equipment contracts that allow encroachment of foreign firms on industries supporting U.S. railroads.

3. Establish appropriately robust standards for cyber and data integrity.

Trucking

1. Create a national apprenticeship program for 18- to 20-year-old drivers to create an increased driver pool for the trucking industry.

2. Modify the Highway Tax Fund to support more comprehensive road and bridge infrastructure improvements.

Air freight

1. Advocate for a practical and effective Transportation Security Administration (TSA) security plan that balances protection of the air cargo industry against government overreach.

2. Provide incentives to encourage continued development of technology for the U.S. air cargo industry, especially to increase the capabilities of the Civil Reserve Air Fleet (CRAF).

Warehousing

1. Commission a study which examines industry best-practices in warehouse location and design to determine the best placement of warehouses and supporting facilities to improve industry efficiency and responsiveness, especially for mobilization.

2. Develop a secure nationwide data exchange platform to allow flexible and accurate sharing of warehousing data across the federal government and with industry partners.

3. Retrofit existing warehouse space to promote downsizing, sub-leasing, or consolidation.

Space

1. Quantify and charge commercial launch customers for holistic launch services.

2. Shift the focus of hypersonic strategy from offensive long-range artillery to logistics.

3. Negotiate (via the United Nations Office for Outer Space Affairs (UNOOSA)) an orbital use-fee treaty among space-faring nations to mitigate growing space debris.

Supporting details and further discussion for each global agility industry's recommendations follow.

Deep-water shipping

Industry definition and current state of play

Oceans cover 70 percent of the Earth's surface. Little surprise, then, that deep-water shipping transports 90 percent of all goods.[3] Some 11 billion tons of cargo are transported by ship each year, with a total value of over $14 trillion in 2019. Deep-water shipping is part of the international maritime transportation system which covers a wide spectrum of activities to include vessel operations, shipbuilding and marine engineering, marine resources (including offshore oil, gas, renewable energy, and minerals), marine fisheries, and other marine activities (mainly tourism and services).[4] This system-of-systems has profound worldwide impacts and is analogous to the circulatory system, carrying life-sustaining goods to all parts of the body—the global economy. Deep-water shipping is dominated by Europe and Asia. The top five ship-owning nations are Greece, Japan, China, Singapore, and Hong Kong.[5] Nine of the top ten containership operators are based in Europe or Asia,[6] and nine of the ten busiest ports are in the Pacific.[7]

The U.S. maritime transportation system breaks into "Deep Sea Foreign" and "Deep Sea Domestic" segments. Approximately 46 firms employ just 2,800 workers.[8] In 2019, U.S. deep-water shipping was worth $59 billion, roughly an 8 percent decrease from the previous year, but by 2024 the industry predicts an 11 percent increase to the U.S. marine freight market worth $65 billion.[9] The largest segment in deep-water shipping is containerized shipping, which accounts for 88 percent of the total market value.[10]

The U.S. accounts for nearly 24 percent of the global marine freight industry by value and moves almost one billion tons of cargo annually.[11] That said, the U.S. is minor player regarding deep-water shipping vessels, with just 0.4 percent of the world fleet. Since 1990, the United States has experienced a dramatic decline in the number of U.S.-flagged ships operating in the international trade sector, from almost 200 vessels in 1992 to 82 in 2017.[12]

The U.S. and China dominate trade in merchandise as well as raw materials.[13] Each nation's massive domestic demand for deep-water shipping should provide their deep-water shipping industries a "clearer or earlier picture of emerging buyer needs," which should pressure firms to innovate faster.[14] And yet, China is a leading deep-water shipper while the U.S. has a tiny share of the world fleet. The difference is ascribed to government policies. China's government policies allow it to apply its national industrial model, targeting key industrial sectors such as deep-water shipping. International competition is undercut by substantial backing by the Chinese Communist Party (CCP).[15] The U.S., on the other hand, has remained committed to the Jones Act, a protectionist approach that has effectively destroyed the competitiveness of the U.S. merchant fleet and its ability to meet DoD's sealift requirements in time of crisis.

Role in support of national security

The National Defense Strategy emphasizes the importance of "resilient and agile logistics" to ensure the DoD can sustain its forces while under "persistent multi-domain

attack."[16] Deep-water shipping, or "sealift" in DoD parlance, plays a major role in national security logistics.[17] The Military Sealift Command (MSC) has primary responsibility for DoD's sealift needs, using a mix of government-owned ships and U.S.-flagged commercial vessels (*i.e.*, the U.S. merchant fleet).[18] A complex series of laws govern the U.S. merchant fleet, with the intent of ensuring the survivability of the fleet both as a commercial activity and as a resource to support DoD's sealift requirements.[19] This includes the Jones Act (part of the Merchant Marine Act of 1920), which requires that all goods travelling between American ports to be transported by ships that are American-built, -owned, -crewed, and registered.[20] The Transportation Department's Maritime Administration (MARAD) has primary responsibility for enforcing these laws and promoting the U.S. merchant fleet.[21]

While deep-water shipping helps sustain DoD's peacetime needs, deep-water shipping truly becomes essential in mobilization. TRANSCOM estimates DoD would transport about 90 percent of military cargo via sealift during a wartime surge.[22] Joint guidance divides sealift during mobilization into three phases, "pre-positioning, surge shipping during initial mobilization, and resupply sustainment shipping."[23] The initial phases rely mainly on government-owned vessels, including the government-owned surge sealift fleet of 15 MSC-owned reserve ships and 46 Ready Reserve Force ships maintained by MARAD.[24] The surge sealift fleet relies on U.S. civilian mariners from the U.S. Merchant Marine to crew these vessels.[25] As an operation matures, MSC typically needs to increase sealift capacity with commercial vessels through programs like the MSP.[26] MSP provides stipends to 60 U.S.-flagged commercial vessels in exchange for their owners' agreements to make those vessels available in times of crisis.[27] Working with these commercial partners, MSC has been able to meet DoD's requirements in recent operations.[28] As anticipated by joint guidance, almost all DoD cargo for these operations transitioned to U.S. commercial vessels by 2009.[29] Despite these successes, there are significant concerns about MSC's ability to meet sealift requirements in a major conflict. For example, during the first Gulf War, a lack of government-owned and U.S. commercial vessels forced DoD to rely on 177 foreign vessels to meet sealift requirements. However, 13 of the ships hesitated or refused to enter the area of operations.[30]

Emerging technologies

Deep-water shipping's most significant innovation in the last several decades was the container, a development the industry continues to capitalize on via increasingly large vessels to achieve economies of scale.[31] Over the last decade, the average and maximum size of containerships have doubled.[32] Some firms have chosen to innovate through specialization. Wallenius Wilhelmsen, for example, specializes in Roll-On/Roll-Off vessels to maximize their ability to flex to varying cargo shapes and sizes.[33]

Looking forward, continued technology development in two areas will likely shape deep-water shipping: automation and emissions reduction. The industry is increasingly looking to automation, including autonomous cargo ships, to streamline deep-water shipping processes and reduce costs. The European AUTOSHIP project has successfully demonstrated an autonomous system on smaller vessels sailing coastal and inland waterway routes.[34] Similarly, the Defense Advanced Research Projects Agency (DARPA) has successfully tested Sea Hunter, an autonomous ship that DARPA believes could revolutionize U.S. maritime operations.[35] Analysis

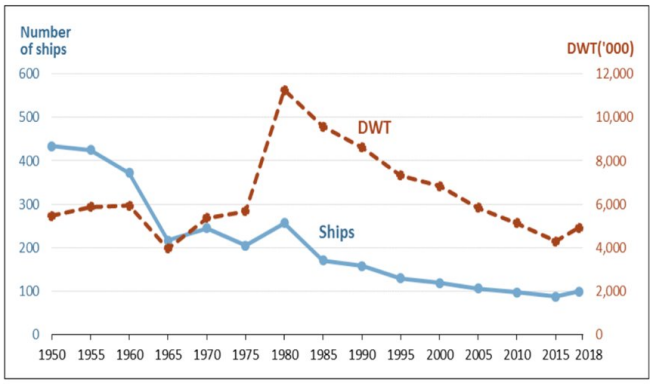
estimates that companies could save tens of thousands of dollars a day by automating just one container vessel.

Issues/challenges

The global deep-water shipping industry is currently facing complex issues attributed to trade tensions, a deterioration in global demand, and the shockwave disruption caused by the Coronavirus (COVID-19) pandemic. Trade tensions cause maritime shipping trade patterns to shift. Trade disputes with China have caused the U.S. and other countries to search for alternative markets and suppliers as trade turned from China towards other markets, especially in Southeast Asian countries.[36] Globalization has significantly contributed to, and has driven, a shift in manufacturing. Since countries like China can offer cheaper labor to lower the cost of manufacturing goods and dependable supply chain activities, many companies sought these international alternatives to domestic manufacturing sources to improve their bottom line.[37] Additionally, to mitigate the impact of the COVID-19 pandemic on freight rates in the containerized, dry bulk, and tank sectors, carriers have executed capacity-management measures and blank sailing (*i.e.*, no sailing or canceled trips) to reduce capacity and increase freight rates.

The TRANSCOM commander has repeatedly testified in recent years that one of his top readiness concerns is strategic sealift.[38] Several studies have raised concerns that DoD may lack the cargo capacity, tankers, and other vessels needed for potential future conflicts."[39] Analysts assign much of the blame to the Jones Act, which has resulted in an undersized U.S. merchant fleet comprised of old ships.[40] The Jones Act may have "preserved a nucleus of a U.S. maritime industry," but that industry is a minor global player with a fleet composition that lacks key types of vessels DoD will likely rely on in times of major crisis (*e.g.*, heavy-lift and tankers).[41]'

A related challenge is the decline in the U.S. Merchant Marine, which DoD depends upon to provide crews for its surge sealift and MSP commercial vessels.[42] According to MARAD and others, there may be sufficient mariners for an initial surge but within a few months, the sealift mission would start to experience significant manning challenges."[43]



Despite the growing volume and value of maritime imports and exports, the U.S.-flagged merchant fleet makes up only 0.4% of the global fleet.[f]

[f] Image source: Congressional Research Service, *Shipping Under the Jones Act: Legislative and Regulatory Background*, R45725 (Washington, D.C., November 21, 2019).

Recommendations

The Jones Act should be modified to account for the modern maritime industry. Specifically, the Jones Act should allow U.S. shipping firms to purchase less expensive foreign-built commercial vessels, increasing the number of ships in the domestic fleet and dramatically reducing shipping costs. Jones Act advocates argue that doing so will force many U.S. shipbuilding yards to close due to overseas shipbuilders' lower labor costs, less aggressive unions, and fewer safety standards. This view fails to account for highly efficient and profitable shipyards in Korea and Europe subject to the same labor and safety standards.[44] Repealing or amending the Jones Act will force U.S. shipbuilding yards to modernize and increase efficiency, or move into other niche industries such as barge construction or U.S. Naval shipbuilding, but in any case, ships will get cheaper.

MARAD should expand MSP to permit participating carriers to use their non-U.S.-flagged vessels for designated domestic routes in exchange for greater and assured access to those ships in a time of national crisis.

DoD should establish the U.S. Merchant Marine as the ninth federal uniformed service, with an active duty and reserve component. Service recognition, to include veterans' and other benefits, might encourage more people to become and remain mariners. The U.S. Public Health Service Commissioned Corps, which serves public healthcare needs in peace but establishes a pool of healthcare providers to support DoD in times of crisis,"[45] offers a good model.

Inland waterways

Industry definition and current state of play

The inland waterway shipping industry comprises the infrastructure, supporting personnel, and physical shipping that provide waterborne cargo transportation along the nation's lakes, rivers, and human-made inland waterways.[46] The system includes nearly 12 thousand miles of maintained waterways with more than 200 operational locks that allow for navigation throughout the network.[47] Many regional shipping companies participate in an industry dominated by three major players (Kirby, Ingram Industries, and American Commercial Lines), representing about 40 percent of the business.[48] According to a 2020 Congressional Research Service report, the system "annually moves over 500 million tons of commodities, including petroleum products, farm inputs (*e.g.*, fertilizers), corn and grains, accounting for four- to five percent of total commercial tonnage shipped in the U.S."[49]

As with most of the rest of the American economy, the COVID-19 pandemic had significant adverse effects on inland waterways shipping. In November 2020, the North American Industry Classification System (NAICS) reported inland waterway industry employment at 20,728 persons.[50] This number represented a reduction from around 22,500 persons the year prior and in immediately preceding years.[51] The same was true for revenue, with a 12 percent loss in 2020 from the previous year to $7.5 billion.[52] The NAICS report

predicts that the inland waterways industry will recover to pre-COVID-19 numbers for employment and revenue by 2025.[53]

The inland waterways industry is significantly smaller than nearly all other transportation industries examined, and it faces sizable threats from a Porter's Diamond perspective. Service buyers are power brokers in the industry. Most can easily change providers, choosing alternate forms of commodity transport should the cost of inland waterway shipping edge too high or the service become too inconvenient. Accordingly, the biggest challenge facing inland waterway shipping is the exceptionally high substitute threats from other well-established shipping modes, including rail, trucking, and pipeline.

Role in support of national security

Although U.S. defense entities do not directly rely on the inland waterway transport industry for survival, they rely on many industries that utilize inland waterway transport as part of a suite of commodity transport options. One of these is the petroleum industry. "The Defense Department's annual fuel bill and utility bill are larger than [that] of all but 15 [of the world's] countries."[54] Inland waterways represent an important facet of America's diverse and robust petroleum delivery system, which also includes pipelines, rail, trucking, and international shipping. A healthy diversity in delivery modes translates to survivability should one or more systems fail due to hostilities or other problems.[55] The U.S. inland waterway industry supports U.S. military mobilization only tangentially. However, inland waterway shipping contributes to national security by providing alternate transport means for U.S. military hardware from specific bases to ports of embarkation.

Emerging technologies

Despite the relative maturity of the inland waterway transport industry, it still incorporates some new technologies and processes to improve. Larger, cleaner barges and boats and digital navigation and information systems help increase safety and efficiency across the industry. However, the nature of inland waterway shipping remains largely unchanged, as "most operators are still engaged in transporting the same commodities, raw materials, and finished goods to the same locations."[56]

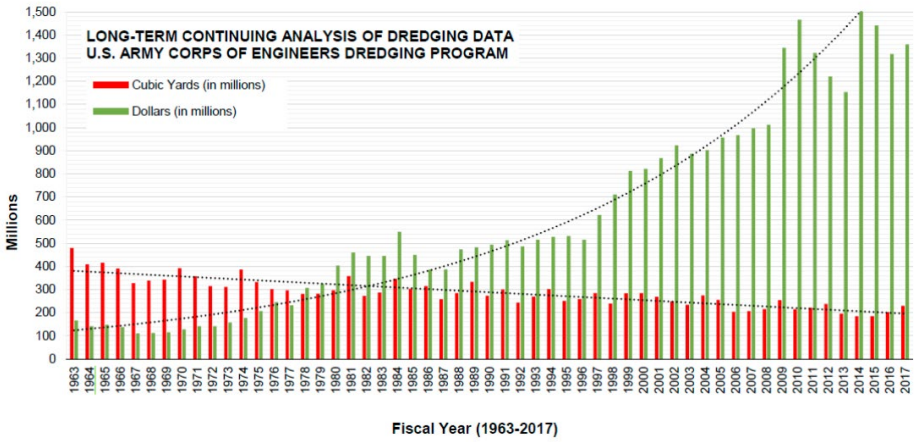
Even so, minor improvements across the industry produce benefits for shippers and customers. New regulations led to double hull requirements for barges, thus decreasing spills and making the industry cleaner. New vessel designs increase fuel efficiency, and shallower drafts allow travel in shallower channels, both leading to cost savings. New paints and coatings result in cleaner hulls with less drag-producing growth.[57] In recent years, satellite-based communication systems and electronic data interchange have become the norm in the industry, which enables managers to track containers and share information between numerous companies involved in shipping goods from origin to destination, creating efficiencies and cost savings across the network.[58]

Issues/challenges

While the inland waterways industry experiences many of the challenges that apply across all global agility elements, it also faces unique issues. American inland waterways infrastructure is aging and, in some cases, obsolete. More than half the locks within the U.S. inland waterway system are more than 50 years old, often exceeding their design life-expectancies.[59] Formerly busy sections of the inland waterway network struggle with dropping throughput due to declining regional industry and system obsolesce, driving customers to other more efficient transportation means. The American Society of Civil Engineers (ASCE) estimates that as much as 49 percent of inland waterway barge traffic experiences delays due to system disrepair, resulting in a D+ score on the ASCE 2021 Infrastructure Report Card.[60]

Inland waterways as a mode of transport lacks the flexibility and agility intrinsic to other substitute modes—new roads and rail are simpler to build than new rivers. They are particularly vulnerable to natural disasters like flooding or drought.[61] When waterway volume flow rates are too high or too low, potential buyers must shift to substitute industries. Many elements of the inland waterway network require periodic dredging and maintenance to remain viable on top of other maintenance requirements typical across industries supporting global agility. Exceedingly high dredging costs make this a particularly challenging enterprise.

Antiquated and obsolete laws, along with rules and practices driving inefficient resource distribution, negatively affect the industry. The 1906 Foreign Dredge and 1920 Jones Acts drive up shipping costs and prevent the industry from employing the latest technologies. Thanks in part to these laws, dredging in the U.S. costs up to eight times more than in other developed parts of the world.[62] Additionally, U.S.-built inland waterway ships cost about four times more than those built overseas, and U.S. crews about seven times.[63] Meanwhile, the U.S. government distributes resources from the IWTF and HMTF across decaying industry infrastructure like peanut butter without regard for targeted investments that would improve system efficiency.



As the U.S. dredge fleet ages, the HMTF pays out more to remove less material.[g]

[g] Image source: U.S. Army Corps of Engineers, "FY20 The Army Corps of Engineers Dredge Schedule." IWR Libraries, April 2021. https://publibrary.planusace.us/#/document/397aee01-0728-4ca0-b4d4-667f3dc7ee28.

Recommendations

Repeal or amend the Foreign Dredge and Jones Acts to encourage competition with foreign-owned dredging and inland waterway shipping firms. Supporters of these acts point out that U.S. dredging companies make significant investments in recapitalizing their own fleets, but U.S. dredges are still (on average), nineteen years older than their European counterparts.[64] Increased competition encourages disruptive innovation, potentially driving efficiency while passing along related cost savings to the industry and its consumers.

Reevaluate IWTF and HMTF distribution focusing on funding projects proportionate to network area use and overall network efficiency rather than the current "one-size-fits-all" approach. Divest underutilized inland waterways system components accordingly. The U.S. government must focus on targeted, efficient, and effective spending with respect to global agility in an increasingly resource-constrained environment.

Restructure inland waterway industry funding methods, shifting towards a public-private partnership approach. Both states and the federal government currently pay for inland waterway-related infrastructure alongside user fees and taxes. Although the inland waterway industry is against additional user-paid taxes through lockage fees or other means, the American public has little appetite for the alternative: matching Congressional appropriations.[65] The fact that this shrinking industry constitutes such a small proportion of overall U.S. inland freight movement makes this especially true. Further shifting costs to users would create a competitive "sink-or-swim" scenario, leading either to industry sustainment or failure in the face of more efficient transportation alternatives.

Ports and harbors

Industry definition and current state of play

According to Rodrigue, "[p]orts are points of convergence between the land and maritime domains of passengers and freight circulation."[66] They connect to facilities, equipment, and transportation systems, such as rail and road, to enable cargo storage, handling, and transport. Additionally, ports have warehouses, docks, and heavy equipment to assist in moving loads from liners or vessels. Looking seaward, harbors serve as safe locations to berth ships and watercraft. Large harbors can host ports.

The port and harbor industry includes companies that operate ports, harbors, and canals. Activities this industry conducts include "loading and unloading cargo from ships, operating lighthouses, arranging paperwork for incoming shipments, operating computer systems to connect cargo with recipients, and providing accommodations to docked vessels."[67] There are more than 300 coastal and inland ports in the U.S., which are "significant drivers of the economy," supporting more than a quarter of total GDP.[68] According to the American Association of Port Authorities (AAPA), "seaports contributed $5.4 trillion to the economy or nearly 26 percent of the total GDP in 2018."[69] The economic impacts of seaports stretch beyond the physical port—the AAPA estimates that 30.8 million jobs were supported by ports in 2018,

up from 23.1 million in 2014.[70] Technological advancements stimulate growth in the market as the size of ships grow exponentially, and as ports incorporate automation to maximize revenue and minimize delays.

According to data reported by Dan Cook from IBISWorld, the industry directly employs nearly 11 thousand people in the U.S., and that number has been steadily rising. Additionally, the total value of industry wages has also grown over the past five years, increasing an annualized 9 percent to $723.2 million. This growth has occurred despite the increase in automation that reduces the overall number of workers. Average industry wages have risen due to competition for trained employees and increased technical operations at ports.[71] Although this decade has seen positive growth, there are some uncertainties about continued revenue growth in the industry.

Role in support of national security

The U.S. must deter malicious intent through deliberate efforts to link ports and harbors with national security. The government acknowledges the importance of ports and harbors, yet the distribution systems and rules governing the HMTF do not allow for efficient use of capital or necessary modernization of infrastructure. The economic importance and visibility of ports make port infrastructure and operations attractive terrorism targets. Attacks on both vessels and the port infrastructure used to move cargo and commodities could damage the U.S. economy by disrupting trade and commerce.

Seaports are critical assets to the United States, not just for the commercial trade and commerce that passes through them, but also for the ability to support our National Security efforts. MarketLine analysts opine that "ports are often viewed by governments as critical national assets."[72]

Pillar II of the 2017 National Security Strategy, *Promote American Prosperity*, points out that a "strong economy protects the American people, supports our way of life, and sustains American power."[73] To maintain our competitive advantage in the industry and our ability to project power globally, the U.S. cannot afford to keep kicking the proverbial can down the road. These delays will result in what one expert referred to as "rusted choke-points."[74]

Nonetheless, the government falls short in linking ports and harbors to national security. This failure is surprising since legislators acknowledge in 2006 that foreign governments have interests in U.S. ports that may extend beyond commercial gain. They stated that "the government of Singapore owns most of a company that operates terminals in Los Angeles, two Chinese companies with close ties to the Chinese government manage terminals in New York, Long Beach, and other places, and the government of Venezuela owns all or part of marine terminal management at ports in Pennsylvania and Maine."[75]

Ports and harbors serve as freight's point of entry into the vast intermodal transportation system running across the U.S. Rail and surface roads are the most common modes that pick up at the port, but those modes also connect to airports and even to spaceports to transport the goods over the last tactical mile, whether on Earth or in outer space.

The benefits to the U.S. government during a mobilization effort are almost incalculable. The DoD relies heavily on the commercial shipping capabilities U.S. ports and harbors offer. For example, in 1991, President Bush signed Executive Order 12743 directing the Secretary of Transportation to support the Secretary of Defense after a declaration of a national emergency "to address the threat to national security and foreign policy of the United States posed by the invasion of Kuwait by Iraq."[76] Fred Baker from the Office of the Secretary of Defense calculated that 6,000 tons of military cargo were moved through U.S. ports per month to support the U.S. response to Iraq's invasion.[77]

Emerging technologies

Ports and harbors benefit from a surprisingly wide field of developments in dredging. A 2000 study of emerging technologies captured both how mundane (though still significant) and novel dredging technologies could be. New technologies ranged from improved gearboxes for cutter heads to autonomous "minidredgers" capable of surgical extraction of contaminated material.[78] A "thumbtack" hydraulic dredge demonstrated its ability to move over 2,300 cubic yards of soil per hour without impacting traffic in and out of the port. Unfortunately, none of these innovations are American-led; European firms developed 100 percent of the emerging technologies examined by the U.S. Army Corps of Engineers. Developments in the U.S. have been less revolutionary (though still useful), including better drag head designs, crab and turtle deflectors and excluders, and automatic ullage (tank capacity) sensors.[79]

On shore, ports continually make updates to handle the additional container volume brought by larger ships and deeper waters. Changing port configurations and incorporating autonomous technologies increases throughput to improve cross-docking processes and intermodal efficiency. For example, the Port of Virginia is installing 86 rail-mounted automated stacking cranes to help expand the port's container handling capability by one million units. [80]

Issues/challenges

Crumbling infrastructure is one of the chief concerns shared by port industry executives, government officials, and consultants. "Erosion of U.S. based infrastructure continues to impair the ability to maintain current capacity and prepare for future needs in the organic industrial base."[81] Trade and industry growth is coming, according to the AAPA; America's trade volume is expected to quadruple after 2030.[82] Additionally, experts predict that "by 2037, the U.S. will export more than 52 million shipping containers through U.S. seaports each year."[83] Experts expect investments in physical port infrastructure will decline because of a shift in investment focus toward more technological solutions.[84] The AAPA estimates the need for $66 billion in "port-related infrastructure" investments over the next ten years.[85] The association claims that a failure to provide adequate infrastructure investments will result in $4 trillion of potential GDP loss by 2025, which will drive $575 billion in additional costs to American businesses and households.[86] This failure would impact every American, costing every household more than $3,400.[87]

Rising sea levels also threaten the industry. Current congressional climate acts focus solely on emissions rather than the long-term effects of sea level rise. "Rising sea level creates

stress on coastal ecosystems that provide recreation, protection from storms, and habitat for fish and wildlife, including commercially valuable fisheries. [88] As sea levels rise, they may compromise port land, infrastructure, and operations.

Recommendations

Make more efficient use of the federal Harbor Maintenance Trust Fund (HMTF). "The HMTF collects its revenue through a 0.125 percent user fee on the value of the cargo in imported containers, which equates to approximately $15 per container box."[89] These user fees are intended to pay for waterside infrastructure needs and operations like dredging. However, the funds must be appropriated from Congress, usually through the U.S. Army Corps of Engineers, for use. The HMTF account currently holds "approximately $9.3 billion in already collected revenue sitting idle in the U.S. Treasury."[90]

Management and release of funds held in the HMTF must coincide with an expansion of industries which support port and harbor infrastructure and maintenance, especially dredging. Repeal or amend the Foreign Dredge Act to allow U.S. dredging firms to be more competitive by enabling them to purchase foreign dredging vessels for domestic work. The requirement to utilize only U.S.-built dredges drives up the cost of acquiring and maintaining the U.S. dredging fleet. U.S. inability to take advantage of cutting-edge dredge technology results in higher operating costs which are passed on to ports and subsequently to consumers and taxpayers. Rapid access to dredging services can be achieved by repealing the Jones Act. U.S. dredging projects cost more than four times that of their European equivalents.[91] Overseas competition will force U.S. dredging firms to develop niches or find ways to increase their efficiency. In either case, consumers will benefit from the reduced costs of dredging through reduced rates resulting from higher volume at ports and shorter routes by container ships seeking deep-water ports.

It may also be possible to shift responsibility for harbor maintenance and port infrastructure more fully to the private sector. Policymakers must re-evaluate the use of the HMTF itself in that the most significant benefits of the fund go to the ports that handle the least amount of cargo. Additionally, naturally occurring ports with little need of dredging contribute meaningfully, but they reap few benefits. The $9.3 billion cash reserve currently held in the HMTF indicates that the 0.125 percent tax is too high. Policymakers should consider a significant across-the-board reduction of the tax to facilitate transferring financial responsibility for dredging and maintenance to municipalities and port owners who could impose a local port tax or other toll collection instrument to fund port and harbor infrastructure. The smaller tax that remains should be dedicated to the maintenance of strategic seaports.

Modify existing grant rules to allow private companies to compete for federal funding and grants based on the amount of funds the company reinvested for port maintenance and modernization. Policymakers may consider providing incentives to adopt new technologies to reduce wait times at docks, boost efficiency, improve resilience, and increase security. They should also carefully evaluate new regulations to ensure compliance will not hinder the incorporation of new equipment or methods intended to make port operations more efficient.

Through grants and taxes, private and public ports would compete for funding based on innovative ideas that gain efficiency over time and transfer to multiple ports or harbors.

Raise docks or relocate facilities offshore to mitigate the negative effects of rising sea level. The government should explore grant and other funding programs that would enable the gradual modernization of ports and harbor infrastructure to withstand higher water. Additionally, it should streamline environmental rules that govern coastal dredging and offshore construction to allow the industry to mount a nimbler response to rising sea levels.

Railways

Industry definition and current state of play

The U.S. freight railway network is considered the most extensive, safest, and cost-effective freight system in the world.[92] Comprised of 7 Class I railroads, 22 regional, and 584 local/short railroads, the industry employs more than 167 thousand workers nationwide and transports approximately 28 percent of the nation's freight over 140 thousand miles of privately owned lines.[93] U.S. railroads serve nearly every industrial, wholesale, retail, and resource-based sector of the economy. It connects ports to urban and rural cities, joins military bases to key logistical nodes, and links U.S. consumers and producers to international trading partners.[94]

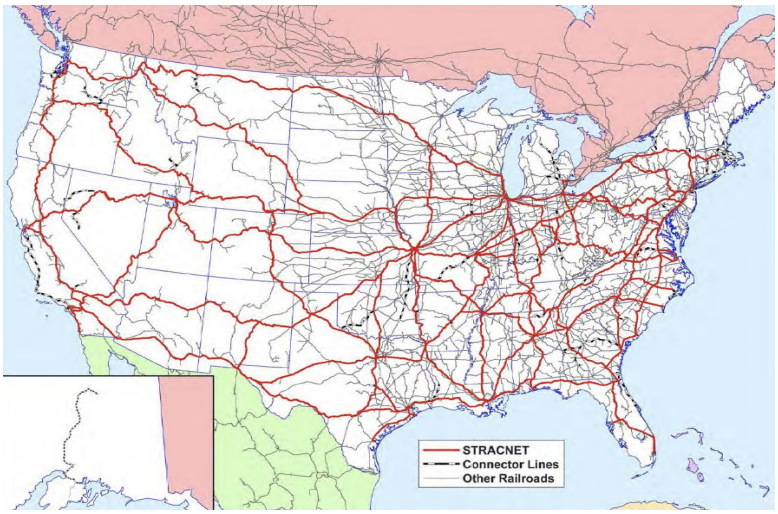
Rail reduces congestion and financial burdens on federally funded U.S. highways, as a single train can haul several hundred truckload equivalents.[95] More than half of rail freight is in bulk commodities such as agriculture, energy products, chemicals, automobiles, and metals.[96] Intermodal services accounted for nearly 25 percent of revenue for major U.S. railroads.[97] Domestically, rail moves most of the 57 tons of freight each American requires annually.[98] International trade accounts for approximately 42 percent of rail carloads and intermodal units while generating 35 percent of rail revenue.[99] In 2020, rail freight generated over $66 billion in revenues, produced a 28.7 percent profit margin, and paid $11.8 billion in wages.[100] The rail industry also boasts significant local impact via jobs and wages. In 2019, the average U.S. Class I freight rail employee earned $132,900 in total compensation,[101] and the industry supported approximately 1.1 million jobs, $219 billion in economic output, and $71 billion in wages.[102]

Despite the relatively high number of competitors, dueling duopolies dominate the industry; the top four companies accounted for approximately 88 percent of total revenue in 2020.[103] Norfolk Southern and CSX compete against each other in the eastern and southern regions of the U.S., while Burlington Northern Santa Fe and Union Pacific compete in the midwest and western regions. Distance, geography, and access create transportation regionalization and, by extension, cartel formation. The threat of new entrants into this highly mature and concentrated market remains low given the significant financial and regulatory barriers to entry, but trucks, inland waterways, and air (or a combination) can be suitable transportation alternatives.

Role in support of national security

The rail industry provides direct support to U.S. mobilization efforts. Railroads facilitate the movement of large military weapon systems for exercises and full-scale mobilization deployments across the Strategic Rail Corridor Network (STRACNET). STRACNET links over 120 military defense installations over 36 thousand miles of interconnected rail corridors and 4,700 miles of connector lines.[104] According to Surface Deployment and Distribution Command estimates, 70 percent of forces would move over STRACNET in a full-scale mobilization.[105] The railroads would likely give the military priority to the network during a national emergency by restricting lower-priority commercial shipments. Additionally, moving heavy military equipment over rail limits damage to and congestion on the U.S. highway system.

Reduced capacity in the rail industry would have disastrous economic consequences to the nation, military, and international partners. Direct impacts range from higher prices, lower profits, and delays as long-distance bulk transportation of goods would rely on more expensive, less efficient modes. The U.S. market would also become less attractive for international companies as delivery prices increase.



STRACNET and connector lines are the civil rail lines most important to national defense.
Credit: Army Surface Deployment and Distribution Command[h]

Emerging technologies

As in inland waterways, advances in new railway technology tend to focus on decreasing costs and increasing both safety and efficiency. Currently, Norfolk Southern is recapitalizing their fleet with longer, heavier, and more fuel-efficient trains, leveraging higher capacity per load while reducing maintenance and operational cost.[106] The industry is also incorporating drones

[h] Image source: U.S. Army Surface Deployment and Distribution Command, "STRACNET Map," October 2018, https://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/RND%20Publications/STRACNET%202018_Reduced.pdf.

and artificial intelligence into operations. Drones reduce the risk, time, and cost of assessing areas and, combined with smart sensors, can add thermal and multispectral information for data analytics to further improve the infrastructure's safety, security, and reliability.[107] Artificial intelligence and deep learning algorithms can also assist with predictive maintenance, emergency notification, and autonomous operations to improve punctuality, reliability, and capacity.[108] The Federal Railroad Administration's current research and development projects include artificial intelligence and machine learning analysis of passive sensor-driven defect and maintenance checks with multispectral, thermal, ultrasonic, vibration, and acoustic technologies.[109] Other research efforts also include alternative fuels for locomotives.[110]

Issues/challenges

The rail industry competes with all other transportation service modes. The U.S. Department of Transportation estimates that demand for freight hauling will grow 35 percent by 2040; however, the rail industry will need to make significant equipment and infrastructure investments to capture and capitalize on the increased market size.[111] For reference, over the past 30 years, America's private freight railroads spent nearly $740 billion on infrastructure and equipment because they own, operate, and maintain everything themselves.[112]

The Staggers Rail Act of 1980 quickly revolutionized a heavily regulated and relatively uncompetitive U.S. rail industry by giving firms discretion to adjust prices and service levels. This ushered in upgraded infrastructure, increased productivity and volume, lower rates, and improved safety. Unfortunately, the measures employed after the passage of the Staggers Act to increase productivity and profitability have been largely exhausted.[113] To ensure continued market share, the industry will require extensive outside funding sources and increased profit expectations.[114] Although railroads currently maintain an advantage in long-distance bulk shipping, autonomous trucking operations and electrification could make trucking more competitive.[115]

Reliance on international manufacturing and growing foreign activities in the U.S. freight rail system threaten the nation's interests. For instance, Beijing's "Made in China 2025" plan aims to establish a global rail sector comparative advantage by building inroads into other country's freight supply chains and rolling stock asset ownership.[116] In less than a decade after entering Australia's domestic railcar market, the China Railway Rolling Stock Corporation (CRRC) decimated Australia's domestic rail manufacturing base.[117] Since 2014, CRRC won subway car contracts for Boston, Chicago, and Los Angeles and a high-speed rail contract to connect Las Vegas and Los Angeles.[118] In 2018, CRRC bragged about operating 83 percent of all rail products globally and questioned how long it would take to conquer the remaining 17 percent.[119] Additionally, a 2017 Oxford Economics study noted Chinese competition in freight railcar manufacturing threatens U.S. economic competitiveness and could eliminate up to 65 thousand U.S. jobs.[120]

In addition to the conventional manufacturing supply issues, safeguarding the increasingly digitized and automated U.S. rail network from cyber risks presents another critical concern. The latest diesel locomotives include hundreds of sensors generating thousands of asset health and performance indicators per mile while more than 25 thousand freight cars are

equipped with remote monitoring devices.[121] Integrating more advanced sensor and automated control technologies present possible data and security vulnerabilities which could provide early warning of military mobilizations.[122]

Like other industries, workforce challenges persist among rail transporters. The industry expects to hire thousands of workers to offset mass retirements and meet expected market demand in the next couple of years.[123] In addition to losing significant experience, the industry struggles to hire more technically knowledgeable and capable workers to support the expanding complexities, market shifts, and sophisticated demands of the business.[124] Additionally, 84 percent of Class I rail employees are unionized by more than a dozen different labor unions governed by The Railway Labor Act.[125] Significant disruption of operations would occur if unionized workers were to engage in a strike or work stoppage, and future labor agreements could significantly increase employment cost. Competing for the required expertise in the open job market, navigating labor issues, and paying extensive retirement benefits will be a delicate balancing act across the industry for the foreseeable future.

Recommendations

In line with the Nobel laureate F.A. Hayek's economic work and Leonardo da Vinci's view on perfection,[126] when looking to solve problems, policymakers should remove elements rather than add them. Policymakers working with the industry need to reassess the effectiveness of all existing and proposed rail safety regulations. For example, the current administration's pledge to require two-person crews on freight trains (despite the Federal Railroad Administration's data-informed objection) seems unnecessary.[127] The railroad industry remains heavily regulated, more extensively than practically any other industry group.[128] Research indicates the regulatory paperwork cost alone increased more than 500 percent over the last 30 years and adds $1.7 billion in compliance costs to the industry.[129] Another recent study found "economic deregulation improved safety more effectively than actual safety regulations by restoring market incentives for firms to pursue safety measures and innovations instead of focusing on complying with regulatory mandates."[130] Good rail business parallels with safe railroads, and the industry has the record, expertise, and incentive to operate both profitable and safe lines. Additionally, although price signals exist in the industry, every Surface Transportation Board market rule and regulation limits industry flexibility and innovation.

Restrictions must be applied to any company featuring strong links to the Chinese Communist Party. The nation needs to protect the rail system's conventional supply chain from foreign domination (*e.g.*, CRRC and rail car manufacturing). The U.S. government, via the Federal Transit Administration, subsidized three of the four rail manufacturing contracts CRRC won in the U.S.[131] In essence, our government financially assisted China's economic and security goals at the expense of American taxpayers, workers, manufacturing base, and security.

Policymakers and industry leaders need to ensure appropriate coordination with federal, state, and local authorities to develop robust standards for cyber and data integrity. These efforts and vulnerabilities are not unique to the rail industry and the businesses are aware of these threats,[132] but complex and advanced technologies present hacking and surveillance opportunities across rail's essential economic and national security architecture. The Federal

Railroad Administration acknowledged existing knowledge gaps and the practical impossibility of universal conclusions over cyber security after conducting a cyber security risk management report for connected railroads in 2020.[133] Vigorously addressing cybersecurity, to include security safeguards on all interfacing components, through collaboration with government agencies and other industries is required to ensure America's vital rail network remains secure.

Trucking

Industry definition and current state of play

Since the early 1900s, commercial trucks have played a vital role in virtually every market. This often overlooked, unglamorous industry has moved literally every commercial product, agricultural foodstuff, and consumer commodity ever produced. The ability to transport these goods from coast to coast while almost instantaneously responding to economic supply and demand changes has made road freight the largest single transportation category in the world. In this critical sector, DoD and Department of Transportation (DoT) leadership must take proactive steps to protect the industry's economic viability and ensure its ability to support national mobilization and contingency surge efforts.

Two main sectors comprise the trucking industry: truckload and less-than-truckload (LTL). The LTL model is more capital-intensive as it relies on an extensive network of hubs, warehouses, and depots, while there is more opportunity for individual owner-operators in the truckload market. The trucking industry employs over 7.5 million people, generates $58 billion in wages,[134]and moves 72.5 percent of the nation's freight.[135] In 2018, over 11.3 billion tons of freight were shipped valued at $11.5 trillion, generating more than $700 billion in revenue across all the trucking sectors.[136] If trucking were a nation, it would have ranked 33rd in GDP in 2018.[137]Industry revenue is expected to increase at an annualized rate of 3.3 percent to $49.8 billion over five years to 2025.[138]

Role in support of national security

The trucking industry not only keeps the U.S. economy moving, but also plays a role in national security. Carriers may apply to the Military Surface Deployment and Distribution Command to become approved carriers. Once approved, the carriers transport military supplies (*e.g.*, aircraft and vehicle parts, uniforms, medicines, fuel deliveries, arms, ammunition, explosives, and other hazardous materials) on time and to the correct destination. Additionally, the trucking industry plays a vital role in mobilization and deployments. A recent example of this importance was the trucking industry's support during COVID-19, transporting personal protective equipment, vaccines, food, and other vital supplies to keep the store shelves full.

Given that more than 70 percent of domestic freight moves by road, any reduction in this capability will necessarily have an adverse impact on the ability of the DoD to mobilize in support of national security, highlighting the importance of keeping the trucks moving. Due to its inherent accessibility, extent, and diversity, the road freight network is vulnerable to terrorism and offers multiple opportunities for adversaries. Internal company efforts have focused

primarily on controlling theft and reducing the inclusion of contraband. However, DoD and DoT leadership must also address these threats and reduce the likelihood of a terrorist attack. The economic health of the U.S. trucking industry and our nation's security are inextricably intertwined in a complex symbiotic relationship. This mutually dependent association will require the DoD and DoT to take proactive action to ensure the industry's long-term viability.

Emerging technologies

Emerging technologies abound in the trucking industry, including advanced pavement monitoring, zero-emission Class 8 trucks, and artificial intelligence. Advanced pavement monitoring relies on moisture and temperature sensors embedded in pavement to collect information on the condition of roads with minimal impact to drivers.[139] This allows engineers and maintainers to anticipate deteriorating road conditions before damage becomes visible, enabling minor preventative maintenance to pre-empt massive, costly, and time-consuming road closures and corrective repairs.[140] While advanced pavement monitoring is beneficial to all motorists, improvements to the roadways and reduction in construction will also improve traffic patterns along well-worn trucking routes to reduce wear-and-tear on tractor-trailers.

Some trucking firms are exploring electric batteries and hydrogen fuel cell engines for future fleets of Class 8 zero-emissions trucks, but the technology is not yet mature enough to support long-haul routes. There is positive movement in the drayage fleet in the Ports of Los Angeles and Long Beach: “the Port is currently engaged in 16 different zero-emission demonstration projects to support development of on-road trucks that we expect will help bring feasible zero-emission technology to the marketplace."[141] Given legislative concerns surrounding climate change, more stringent environmental requirements are likely to be imposed on the trucking industry. The zero-emission Class 8 trucks will need to meet the distance required at a price point owner-operators can afford in order to meet the emission goals set by cities and states.[142]

Finally, artificial intelligence and its role in autonomy may substantially change the trucking industry. Autonomous trucks rely on proximity sensors, cameras, lidars, and radars feeding data to a computer, which controls the vehicle using skills learned through training and simulation. Unlike passenger vehicles, trucks (particularly long-haul tractor-trailers) generally follow fixed, predictable routes and spend most of their time on highways which contain fewer obstacles and are easier to navigate than surface streets. Trucks are also a better platform for autonomy, with their large size providing more power for computers and an improved field of view for sensors, which can be mounted higher off the ground. Autonomous trucks currently in development demonstrate more efficient braking, acceleration, and optimized in-lane variations, resulting in 10 percent greater fuel economy and reduced tire wear.

Issues/challenges

The trucking industry faces several challenges. Specifically, a driver shortage and failing infrastructure pose critical threats to the industry. The American Trucking Association estimates the current shortage of drivers is over 63 thousand,[143] with estimates that the shortage will exceed 160 thousand by 2028. For many, truck driving is an undesirable job, and there are few

candidates to replace retiring drivers. The median age of over-the-road truck drivers is 46, compared to 42 for all U.S. workers. Some sectors have an even higher median age, such as private fleet drivers, where the median age is 57 years old. Compounding the issue is the requirement that drivers must be at least 21 to operate a rig. Often, individuals with the potential to be truck drivers have already found careers in construction, retail, or other industries before reaching the eligibility age.

The driver shortage further exacerbates the adverse health effects of the existing fleet. Long working hours, extended time away from family, lack of sleep, and a sedentary lifestyle contribute to severe health conditions such as sleep apnea, obesity, heart disease, and diabetes. Additionally, the lifestyle does not encourage female drivers to participate in the industry. According to the Department of Labor, only 6.6 percent of truck drivers are female, despite representing nearly 47 percent of all U.S. workers.[144]

The second critical issue in the trucking industry is the condition of the roads and bridges. According to the ASCE, 43 percent of the U.S. public roadways are graded as "poor" or "mediocre."[145] Road conditions lead not only to increased maintenance costs on the trucks themselves, but also to traffic delays on already congested roadways. Higher shipping demand and the corresponding increase in road usage, weather, and continued inadequate funding from the Highway Tax Fund further exacerbate this issue. In addition, the mediocre and poor road conditions have a ripple effect, causing delays in deliveries, inefficiencies in transportation, and decreased customer support. According to the American Transportation Research Institute, traffic congestion costs the trucking industry $74.5 billion annually, 1.2 billion in lost hours, and the equivalent of 425,533 idling drivers.[146]

Recommendations

The issues and challenges for the trucking industry cannot continue unchecked without having significant impacts on the U.S. economy. To mitigate potential adverse outcomes and ensure the long-term health of road freight, DoD and DoT should create a national apprenticeship program for 18- to 20-year-old drivers, expanding upon the DRIVE Safe Act. This program will enable the industry to provide a path for younger individuals otherwise precluded from entering the workforce until age 21. Trucking firms should consider recruiting under-represented demographics, especially women, when trying to expand their driver pools.

The government should create regulations and tax benefits that encourage the widespread implementation of autonomous trucks as soon as possible. Supporting this technological leap will lessen the impact of driver shortages, drastically increase safety, and increase industry profits. In addition to lower driver labor costs, automation has the potential to decrease fuel consumption and increase efficiency and utilization rates by eliminating the need for driver rest periods. These cost savings will be returned to the industry, increasing overall profit margins. Industry should carefully consider second and third order economic effects, in that autonomy may result in structural unemployment as drivers find themselves replaced by machines.

The Highway Tax Fund should be modified to fund comprehensive road and bridge infrastructure improvements. It is currently funded via a consumption tax on gasoline purchases.

Over time, this funding method has become increasingly inadequate. As electric and hybrid vehicles become more common and standard combustion engines become more fuel-efficient, this funding issue will intensify. An adjustment to the Highway Tax to include a usage fee or toll combined with the consumption tax could be a huge step in providing resolution to the underfunding of infrastructure. Additionally, the modified Highway Tax should be indexed to inflation. The ASCE estimates that $53 billion (vice the current level of $41 billion) should be spent annually to rehabilitate pavement and make other improvements to road infrastructure. While this represents a significant increase in spending to be passed on to drivers and taxpayers, it will be offset somewhat by the lower number of repairs motorists must perform on their vehicles annually due to poor road conditions—an annual average of $130 billion.[147]

Air freight

Industry definition and current state of play

In the most basic terms, air freight is the movement of goods from one location to another using aircraft. Air freight is characterized by speed and rapid response to the requirements of emergency transport, such as transporting perishable goods or medical material. The air cargo industry is growing because of increasing globalization. Online shopping and e-commerce increasingly rely on manufacturing and labor from inexpensive regions, which feeds into global trade, and ultimately growth and change for air freighters.[148] The global air cargo industry is massive in scope and scale and plays a significant role in the U.S. GDP by supporting 65.5 million jobs and adding $2.7 trillion in global economic activity.[149] The total impact on the U.S. economy is equally impressive—the overall airline industry (*i.e.*, cargo and passenger movement) helps drive $1.7 trillion in U.S. economic activity and more than 10 million U.S. jobs.[150]

Global air freight capacity comes from a combination of passenger airlines and all-cargo carrier aircraft.[151] Air freight is one of the driving forces behind the economic connection between different regions as it may have economic, political, and social implications. It is innovative, relying heavily on new electronic technologies and offering a wide range of transport and logistical products through dedicated "specialist" cargo operators. Furthermore, air freight is the safest of all the other land- and sea-based transportation modes, as cargo dispatched by air moves with minimal handling and rigorous safety controls at airports. It features a low risk of theft and shipment damage, and because the time in-transit is short, insurance premiums are usually low.

Role in support of national security

The U.S. air cargo industry plays a role in national security as a hard power tool. It serves as a significant partner in national mobilizations via the CRAF.[152] Air cargo capabilities play a pivotal role in advancing U.S. national priorities; however, this critical component of national security is not impenetrable. The international air cargo market is profoundly impacted by globalization. The global air cargo industry is highly interconnected; its complexity and interdependency mean that one small change can snowball. The U.S. must

establish a genuinely global and resilient air cargo industry to ensure a competitive advantage over our adversaries and bolster our national security in the era of great power competition.

Emerging technologies

Air freight benefits from a broad spectrum of technologies dealing with the entire supply chain, from cargo and passenger security screening to the delivery platforms and systems. Like other industries, digitization and autonomy play a huge role in making air freight cheaper, safer, and easier.[153] Digitization and smart data sharing allow customers to easily track shipments, carriers to streamline invoicing, and software to detect inefficiencies in the supply chain.

Security is significant in the air freight industry, and it is rapidly evolving. Cargo screening is a potentially time-consuming process for air freight, but this process can be expedited by pushing security measures upstream. For example, entities that can demonstrate their supply chains meet rigorous physical security protocols could be allowed to bypass airport or planeside screening processes.[154] Digitization and autonomous or robotic handling may enable these shipments to be quickly sorted as shipments are consolidated for air transport. Because air freight is inherently cost-sensitive, these small improvements in supply chain processes directly translate into better industry practices and better performance in the highly competitive industry.

Issues/challenges

"Air cargo demand is not just recovering from the COVID-19 crisis, it is growing," declared the International Air Transport Association on Twitter. With demand at 9 percent above pre-crisis levels, one of the main challenges for air cargo is finding sufficient capacity. It also highlights the need for clarity in planning for a safe industry restart.[155] Because of the dependence air freight has on passenger aircraft belly space, passenger airlines' recoveries from COVID-19 will be crucial for providing belly capacity for air cargo—but forecasting these recoveries is challenging. Factoring these estimates into air cargo operations is critical to re-establishing air freight capacity.

Compliance with air freight security regulations is reopening a long-running policy debate over the best way forward for the industry between a risk-based approach or comprehensive physical checks of all air cargo. Air freight security challenges include the transportation of dangerous goods, threat of terrorism, and cyberattacks. There is a great deal unknown about what the TSA regulatory requirements will be, and it will continue to remain a significant concern for the air cargo industry.[156] Fuel costs are also a challenge within the air freight industry. Fuel and shipping prices are closely linked as carriers strive to keep up with costs or incur losses. Depending on supply and demand elasticities, if the shipper incurs more charges for transporting the goods, the recipient may pay more to offset the additional cost, and, likewise, consumers may end up paying more.

The current climate of great power competition has seen China create new laws that approach security as a multifaceted concept of military, political, technological, cultural, and economic aspects, emphasizing the economic piece of the equation. Chinese policies optimize

the environment for local carriers while U.S. firms are forced to compete at a disadvantage. This protectionism is a challenge as U.S. firms strain to maintain their market share versus heavily subsidized competitors.

Recommendations

DoD should advocate for a practical and effective TSA security plan that will safeguard the air cargo industry while avoiding burdensome bureaucracy. It may be beneficial to leverage the "Iron Triangle," as agencies and firms will undoubtedly argue for their interests in negotiations. It is vital that the approved security plan avoid overreach which could inadvertently create barriers and negatively impact our competitive edge over China and Russia in the international air cargo market. Additionally, policymakers should consider the air freight industry's role in countering global pandemics such as COVID-19 and other contingencies. Special rules should be developed to ensure the flow of critical medical supplies and equipment during a crisis, removing barriers and restrictions to the industry.

The government should make available grants, stipends, and other incentives to encourage the continued development of technology in the U.S. air cargo industry by the private sector to remain competitive with Chinese and Russian counterparts. Policymakers must exercise caution—the incentives they offer must not lead to unprofitable stovepipes, and research and develop efforts must remain open and competitive. Private research should include the development of technologies and procedures to maximize the use of the Air Mobility Command's cargo platforms and expand their roles and functions in conflict. The DoD should explore options to incorporate these innovations for possible use on CRAF air platforms while expanding overall CRAF capacity.

Warehousing

Industry definition and current state of play

The warehouse industry is complex; not only is it interconnected with the economic prosperity of a nation, but the type of warehouse needed also depends on the nature of materials that the facility will handle. The global warehousing market was valued at approximately $245 billion in 2020, and it is forecasted to grow at a compound annual growth rate of 7 percent between 2020 and 2024 to touch the $326 billion mark by the end of 2024.[157] Real estate developers cannot build warehouse space fast enough. Craig Meyer, president of JLL's Americas industrial division, explained a recent situation where a retail-related company requested a lease on a 1.2 million-square-foot warehouse space in Delaware and moved in almost immediately to begin fulfilling orders, which is unheard of since leases typically take up to nine months to negotiate.[158] As the demand for warehouses increases, all aspects of the warehousing industry need to be evaluated when considering the ability of the U.S. to respond to surge and mobilization requirements.

Role in support of national security

The warehousing industry is in global shortage, making the rivalry among existing competitors extremely high. This rivalry includes global companies (FedEx, UPS, Amazon) and nation-states (China, India, United States, European Union) who rely on warehouses to further their interests. India and China are predicted to be the future growth-oriented markets in the warehousing industry due to the surge in manufacturing facilities, container ports, and the growth of the e-commerce industry.[159]

China currently has a competitive advantage in the warehousing industry; it has established a nationwide plan to build strategically placed, state-of-the-art warehouses to accommodate its growing demand. Additionally, China has centralized guidance and regulations that govern the warehousing industry – from the type of buildings constructed, their locations, and their national standards. Fortunately, there is a natural economic balance since China's economy largely depends upon the consumerism of the U.S. and Europe. This balance places the U.S. and China in a perpetual state of economic competition that is already driving the U.S. warehousing industry to innovate. While industry-wide standardization provides a near-term advantage to China, the rigidity that comes with standardization may present new challenges should exogenous events, disruptive technologies, or a sweeping change to warehousing needs arise.

The DoD acknowledges that both the warehousing shortage and corresponding industrial revolution in warehousing present a fantastic opportunity for military warehousing and logistics. 'Smart warehouse' pilots using 5G exist at Naval Base San Diego and Marine Corps Logistics Base Albany.[160] These pilots may determine whether private industry warehousing solutions can translate into military warehousing and logistics in both peacetime competition and volatile, uncertain, complex, and ambiguous wartime environments.[161] Any efficiencies gained from these smart warehouses must be captured and expanded to realize defense warehousing operations capable of meeting the demands of the warfighter.[162]

Emerging technologies

The drive to make existing warehouses more efficient and cost-effective has led to a revolution in warehousing technology. This revolution introduces new platforms like 5G, Internet of Things (IoT), AI, and machine learning (ML). These emerging technologies and the introduction of robotics allow warehouse workers and managers to maximize productivity while also increasing safety. This 'smart warehouse' concept is gaining traction across the industry, from 'smart hub' distribution in Bahrain to robotic grocery baggers in the United Kingdom and United States.

Bahrain's 'smart hub' concept is exciting since it addresses sharing proprietary data and creates quicker transactions through pre-approved customs clearances. Moreover, adopting private sector advancements to defense warehousing and logistics operations is relatively simple. The grocery-picking robot concept translates to a maintenance warehouse where repair parts for military vehicles are quickly picked, packaged, and sent to units worldwide. Once the inventory for a particular part is low, the AI and ML will automatically order more parts based on demand.

At the same time, the robots restock the bins with what is currently available in the warehouse. This part-picking robot concept would require an initial investment to retrofit existing warehouses, but that investment will significantly decrease personnel costs while increasing warehouse safety. Additionally, the inventory visibility created by AI and ML provides manufacturers and suppliers with visibility, predictability, and the data necessary to structure procurement contracts correctly. Overall, 'smart warehouse' concepts can save the DoD billions of dollars per year through a decreased personnel costs, increased warehouse safety, and data-informed procurement contracts.

Issues/challenges

Amplified demand through e-commerce leaves the world with a warehouse shortage, driving up the cost of current and future warehouse leases. Current and future warehousing shortages create the need to make current warehouses more efficient while also putting them in the proper location to serve their customers. Simply put, the warehousing shortage is creating an industrial revolution in warehouse location and design.

General-purpose warehouse space requires several acres of undeveloped land located close to the highway, rail, airport, or seaport access. Unfortunately, most of these areas in the U.S. and Europe are already developed or restricted for environmental conservation or encroachment concerns. Commercial real estate developers are looking to convert unconventional spaces closer to urban population centers such as abandoned shopping malls and post-COVID-19 excess office space (where employees will not return) into warehouse space. According to Coldwell Banker Richard Ellis, Inc., 24 former retail properties in the U.S. have been or are currently redeveloping into warehouses or distribution facilities.[163] The necessity of moving the last mile delivery warehouses closer to urban population centers will also impact the ability of workers to afford living in highly dense metropolitan areas. Additionally, since potential warehouse space is limited in larger markets like the U.S. and Europe, nation-states with available acreage and more accommodating zoning regulations are gaining market share.

The ability for current and future warehouses to meet the growing needs of a changing supply chain requires innovation in warehouse design. When establishing or restructuring a warehouse, one of the essential activities is establishing a process flow—determining the standard set of operations within the warehouse to collect data and maintain warehouse inventory awareness. The establishment of these workflows ensures proper data collection, location tagging, and inventory tracking. These are the guideposts that guide warehouse operations; additionally, documenting and mapping out the processes enable the organization to flag where technological advancements (*e.g.*, radio frequency identification, scanners, or conveyor lines) will make the operation more efficient. Conversely, the drive to make existing warehouses more efficient and cost-effective has led to a revolution in warehousing technology. The introduction of new platforms like 5G, IoT, AI, ML, and robotics allow warehouse workers and managers to maximize productivity while also increasing safety. The inventory visibility created by these emerging technologies in the 'smart warehouse' concept provides manufacturers and suppliers with predictability to forecast future orders while also providing government contract personnel with the data necessary to structure procurement contracts correctly.

Recommendations

The government should perform periodic nationwide assessments that look at location and design (to include process flows and internal controls), then develop a solid business case analysis that determines the best placement of facilities to maximize responsiveness or identifies existing locations' infrastructure and building requirements to improve effectivity and responsiveness. This effort should include a mandate that all federal storage/warehouse facilities undergo a design strategy assessment which documents best practices, process flows, and internal controls. DoD should redesign sub-optimized warehouses and require the inclusion of necessary warehouse software. Develop partnership agreements and establish programs to upgrade federal facilities and grants to modernize private warehouses determined to be of strategic value for surge or mobilization.

Develop a cyber secure nationwide data exchange platform (smart hub, smart pass concept) through the Chief Data Officers Council. Propose requirements to establish whole-of-nation and all-federal agency standards for data exchange between automated information systems for logistics and supply chain management, both across the federal government and with industry partners. Make this a statutory requirement and subsidize industry to implement this protocol. Data exchange standards will better enable federal responses to disasters or national mobilization, but policymakers should consider the costs regulatory burdens this could create for warehousing firms and ensure they balance against the advantages gained during crises.

Retrofit existing warehouse space utilizing emerging technologies, thus creating space for sub-leasing or consolidation. Conduct a strategic relook at inventory storage protocols to reassess storage costs, storage locations to improve response efficiency. The status quo for current inventory procedures and storage methodologies will not advance the U.S.'s capability nor responsiveness.

Space logistics

Industry definition and current state of play

Though the definition of space logistics is still emerging, industry experts agree it entails the direct and indirect services and infrastructure supporting space activities. The U.S. Space Force (USSF)'s capstone doctrine document calls for projecting power "in, from, and to the space domain" to secure the free and peaceful use of space for all comers.[164] The USSF recognizes space mobility and logistics as key to cross-domain military power projection, but most of the current and forecasted activity in the space domain is commercial. Launch providers are the leading players in this industry, likened to long-haul truckers for space. Their customers include a mix of national security and private companies aiming to open a new commerce domain for terrestrial and outer space applications.

Analyzing the space logistics sector's contribution to the U.S. and global economy is challenging. Statistics exist for the overall space economy but are subjective depending on the source. The U.S. Bureau of Economic Analysis recorded the latest official space economy

numbers in 2018. Their report says the space economy stood at $177.5 billion, amounting to 0.5 percent of GDP, and supported more than 183 thousand private-sector jobs.[165] UBS, the Swiss-based financial firm, estimates the global space economy will increase to $1.1 trillion by 2040, while Merrill Lynch forecasts it to soar to $2.7 trillion by 2045.[166] Bottom line, the space domain continues to grow and the logistics behind it will follow suit.

Role in support of national security

Speed is always a concern in mobilization efforts, and hypersonic rockets with significant payload capacity, such as SpaceX Starship that can carry 150 short tons, offer a glimpse of the possibilities.[167] Capability for this type of resupply existed in the 1980s, but launch costs were the limiting factor. SpaceX changed the launch landscape with their Falcon 9 rocket in 2015, lowering the cost-per-launch from $1.6 billion to $62 million.[168] Both increasingly frequent launch attempts and technological advances lend credibility to military uses of space for mobilization and sustainment.

Resupply to the International Space Station occurs regularly; the last orbital mission contained 8,000 pounds or 4 tons of cargo.[169] Suborbital cargo capacity has the potential to be much larger, offering rapid response to contingencies, both military and humanitarian, anywhere in the world in a matter of hours. SpaceX is testing this capability soon, providing confidence to stakeholders and sending a strategic message to current and potential competitors.[170] The refinement of this technology will change the paradigm on how DoD prepares and executes space missions in the future.

Unsurprisingly, China is the pacing threat for space logistics. China's launch rate and rapid development of reusable rockets are approaching parity with U.S. capabilities. On March 9th this year, China and Russia announced an agreement for establishing a joint moon base for research.[171] Experts suspect more than research will occur, given the moon's rich mineral deposits and its potential to serve as a hub for logistics and mining operations. Beyond the agreement with China, Russia's ambition to gain dominance in space is mostly on paper due to their inability to fund space missions against competing national priorities. A Sino-Russian alliance in space is troubling for the U.S.; Russia's intellectual property wealth and China's monetary wealth make for a highly capable and potentially dangerous space alliance.

Emerging technologies

As the newest global agility system element in a rapidly growing technology field, nearly all developments in space logistics could be considered "emerging." Evolving operational models unique to space operations will determine how national security space will capitalize on the expansion of commercial services. For example, constructed next to White Sands Missile Range to take advantage of the vast land and proximity to El Paso, the state-funded Spaceport America site was born out of demand from its primary customer, Virgin Galactic. Because Virgin Galactic air-launches spacecraft (via a runway versus a rocket), their space operations pose less risk to surrounding communities and are less disruptive to other air traffic than traditional vertical rocket launches. Spaceport America provides services akin to a port authority, offering commercial customers compliant infrastructure and business services to

support "plug-and-play" operations. Although not as prominent as Cape Canaveral or Vandenburg Space Force Bases, Spaceport America offers a new model for the industry.

Commercial in-space transportation, also known as interstellar logistics, is a rapidly evolving area of space logistics. Several companies currently offer satellite services while developing future capabilities for intra-orbital resupply. Northrop Grumman's subsidiary, Space Logistics, earlier this month successfully docked its Mission Extension Vehicle (MEV) to a client satellite providing essential guidance and propulsion extending its life cycle by another five years.[172] DARPA also selected Space Logistics to further develop the MEV concept to add robotic arms that would enable both existing satellite maintenance and future on-orbit construction.[173] The space logistics industry already benefits from a bevy of innovators—good ideas are not hard to find. Rather, the industry's real challenge will be building good government partnerships to shape the business environment that will allow firm profits to flourish while also advancing the U.S.'s competitive advantage in space.

Issues/challenges

Government-owned launch facilities occupy prime beachfront real estate on east and west coastlines, precluding any alternative revenue-generating commercial uses. For every attempted launch, the Federal Aviation Administration must clear surrounding airspace, the U.S. Navy must cease nearby operations, and the U.S. Coast Guard must clear the area of commercial vessels. Sometimes, this resource-intensive coordination is all for naught, as a successful launch may require up to ten failed attempts.[174] Upon ignition, rockets spew unstable, pressurized, and toxic gases at temperatures over 5,800 degrees Fahrenheit against the concrete pads and steel towers they straddle, requiring 290 thousand gallons of water every 41 seconds to dampen acoustics and minimize supersonic pressure waves that could destroy the rocket itself and kill anyone within close range.[175] This all occurs on DoD property with a single military officer bearing responsibility for the safety of personnel, property, and infrastructure associated with each launch.

Despite the expense and responsibility DoD assumes, military space launch requirements comprise a small fraction of total launches. Commercial launch activities by companies such as SpaceX, United Launch Alliance, and eventually Blue Origin already represent most of the space launches, and the USSF predicts commercial launches will outpace government launches three-to-one over the next decade.[176] The DoD is not manned nor funded to sustain its current operations, maintenance, and oversight role of the increasingly commercial space industry.

Further, space debris is crowding low-Earth orbit not because engineering solutions do not work, but because satellite operators continue to launch new satellites with no limitations or regulations on life cycle management. In fact, removing space debris may even encourage satellite operators to launch additional satellites, further exacerbating space overcrowding. Satellite launches create a negative externality; more satellites increase collision risk, but individual operators do not bear the social cost they impose on the collective space community for each satellite they launch. The United Nations Office for Outer Space Affairs (UNOOSA) manages international space law treaties including the requirement to register all space

objects,[177] but like all international treaties, a sovereign country can defect from a treaty at any time, either in protest or to meet their own national interests.

Recommendations

USSF should quantify and charge commercial customers for holistic launch services, defined as direct incremental costs plus overhead expenses, to maintain oversight and responsibility for space launch infrastructure. Alternatively, DoD might consider completely turning over operations to the private sector with agreements for prioritization of national security payloads.

Also, DoD should shift hypersonic strategy emphasis from offensive long-range artillery to logistics. The U.S. has redundant strategic kinetic strike capabilities with intercontinental ballistic missiles and bomber aircraft; if a great power threat materializes, the military's greater challenge will be in transporting cargo and passengers to the battle rather than conducting long-range fires. Resupply in a contested environment will strain U.S. military logistics, so adding the flexibility of on-demand hypersonic cargo transportation will mitigate risk and provide the combatant commander reach and depth on the battlefield. While hypersonic logistics will likely be costly, it will also force the adversary to expend resources and effort to counter the capability.

Finally, policymakers should negotiate an orbital-use fee treaty among space-faring nations (via UNOOSA) to correct the negative externality imposed by satellite launches and mitigate the space debris "tragedy of the commons." UNOOSA should simultaneously promote the use of satellite life cycle extension modules and work with industry to develop a comprehensive service to collect and dispose of space debris.

Industrial Security: The Problem with Digitization

> *"We will bankrupt ourselves in the vain search for absolute security." -- President Dwight D. Eisenhower*

Over the years, global agility industry consolidation and digitization have significantly increased system vulnerability and the potential consequences of nefarious-actor attacks. Global agility industries have largely moved away from historically decentralized, analog, stand-alone systems operated and maintained by armies of employees to centrally managed, computerized, and highly interconnected systems. While these moves have increased global agility, industry efficiency, productivity, and profitability, they have also created new vulnerabilities and increased the potential for catastrophic failure due to declining system redundancy.

The Colonial Pipeline ransomware shutdown of May 2021 provides an interesting case study into the nexus of rising cyber threats with global agility system redundancy cutbacks. The Colonial Pipeline is an essential cog in the suite of industries that support energy production in the U.S. and worldwide. Along with the greater U.S. energy market, these industries gone to great lengths in recent years to eliminate redundancies, streamline, and digitize.[178] Four oil refineries in Pennsylvania and New Jersey that formerly provided gasoline to much of the east

coast have shut down since 2010 because it is less expensive to ship gasoline from refineries in Louisiana than to produce it locally, effectively trading system resiliency for efficiency.[179] Additionally, the Colonial Pipeline cyberattack impacted the southeastern states much more than their northeastern counterparts. Southern states lacked other energy-related redundancies, including access to deep-water shipping ports and fuel storage capacity.[180] An equally important reason for the system's failure was the attack itself, carried out remotely from 6,000 miles away in Russia in a manner impossible two decades ago.

Despite the risks, the efficiencies realized through industry digitization are too significant to justify re-adopting inefficient analog systems to promote greater security. However, adequate digital security is essential to system survivability. Established legacy companies, such as those that dominate energy production in the U.S., tend to hold an ineffective "this-is-the-way-we've-always-done-it" mentality regarding new risks, including cyberattacks, according to Michael Davis, an economics professor at Sothern Methodist University's Cox School of Business.[181] This is unacceptable in a world that is exponentially moving towards digitization. Similarly, there is a fine line between investment in necessary and justifiable system redundancy and wasteful spending on outdated and inefficient systems in a resource constrained environment. U.S. lawmakers must take a hard look at what redundant global agility components to prop up vice what to allow to fail in the open market.

The Colonial Pipeline ransomware attack demonstrates some of the vulnerabilities of digitization and standardization.[i]

[i] Image source: Colonial Pipeline Company, "Colonial Pipeline System Map," 2021, https://www.colpipe.com/news/in-the-news/colonial-pipeline-101-know-colonial.

Conclusion

"I don't know what the hell this 'logistics' is that Marshall is always talking about, but I want some of it."
-- Admiral E.J. King

The National Defense Strategy emphasizes the importance of resilient and agile logistics to ensure the DoD can sustain its forces while under attack. In an era of great power competition, anti-access and area denial attacks perpetrated by China and Russia reinforce the need for the US to sustain a comprehensive, strategic, and robust global agility system. Global agility's interconnected links and nodes ensure not just DoD's ability to project power, but also the entire nation's economic health. Intermodal transportation and distribution of goods among deep-water shipping, inland waterway transportation, ports and harbors, warehousing, railways, trucking, air freight, and space logistics nodes enable a healthy domestic industrial base and competitive advantage in international trade; moreover, they also connect warfighting domains via an interlocking network of industries.

While pockets of individual industries show worrisome signs of stagnation, others have leveraged market incentives to advance the profitability and competitiveness of their firms to great advantage. When government intervenes to align public-private incentives rather than to protect special interests, the global agility system, and indeed the entire nation, benefits. To build on those elements of good governance already in place, Team Global Agility recommends the following policy options:

Deep-water shipping

1. Modify the Jones Act to allow U.S. shipping firms to purchase less expensive foreign-built commercial vessels, increasing the number of ships in the domestic fleet and dramatically reducing shipping costs.

2. Expand the Maritime Security Program (MSP) to permit participating carriers to use their non-U.S.-flagged vessels for designated domestic routes in exchange for greater and assured access to those ships in a time of national crisis.

3. Establish the U.S. Merchant Marine as the ninth federal uniformed service, with an active duty and reserve component, to encourage more people to become and remain mariners.

Inland waterways

1. Repeal or amend the Jones and Foreign Dredge Acts to encourage competition with foreign-owned dredging and inland waterway shipping firms.

2. Reevaluate the Inland Waterways Trust Fund (IWTF) and Harbor Maintenance Trust Fund (HMTF) distribution, focusing on funding projects proportionate to network area use and overall network.

3. Restructure inland waterway industry funding methods via demand-risk public-private partnerships.

Ports and harbors

1. Expand U.S. dredging fleet capacity to make full and timely use of the HMTF.

2. Link ports and harbors with national security to provide greater weight to requests for resources by port operators.

3. Establish incentives, via heightened consideration for grants, for increased private investment in port modernization and maintenance.

4. Explore methods to help port operators modernize facilities to combat rising sea-levels.

Railroads

1. Review existing and proposed rail safety regulations in order to identify and remove barriers to industry innovations in safety, efficiency, and maintenance.

2. Implement restrictions on government-sponsored rail equipment contracts that allow encroachment of foreign firms on industries supporting U.S. railroads.

3. Establish appropriately robust standards for cyber and data integrity.

Trucking

1. Create a national apprenticeship program for 18- to 20-year-old drivers to create an increased driver pool for the trucking industry.

2. Modify the Highway Tax Fund to support more comprehensive road and bridge infrastructure improvements.

Air freight

1. Advocate for a practical and effective Transportation Security Administration (TSA) security plan that balances protection of the air cargo industry against government overreach.

2. Provide incentives to encourage continued development of technology for the U.S. air cargo industry, especially to increase the capabilities of the Civil Reserve Air Fleet (CRAF).

Warehousing

1. Commission a study which examines industry best-practices in warehouse location and design to determine the best placement of warehouses and supporting facilities to improve industry efficiency and responsiveness, especially for mobilization.

2. Develop a secure nationwide data exchange platform to allow flexible and accurate sharing of warehousing data across the federal government and with industry partners.

3. Retrofit existing warehouse space to promote downsizing, sub-leasing, or consolidation.

Space logistics

1. Quantify and charge commercial launch customers for holistic launch services.

2. Shift the focus of hypersonic strategy from offensive long-range artillery to logistics.

3. Negotiate (via the United Nations Office for Outer Space affairs (UNOOSA)) an orbital use-fee treaty among space-faring nations to mitigate growing space debris.

Appendix A: Porter's Diamond (Theory of national competitive advantage of industries)

"You can't have a healthy society unless you have healthy companies that are making a profit, that are employing people, and that are growing." – Michael Porter

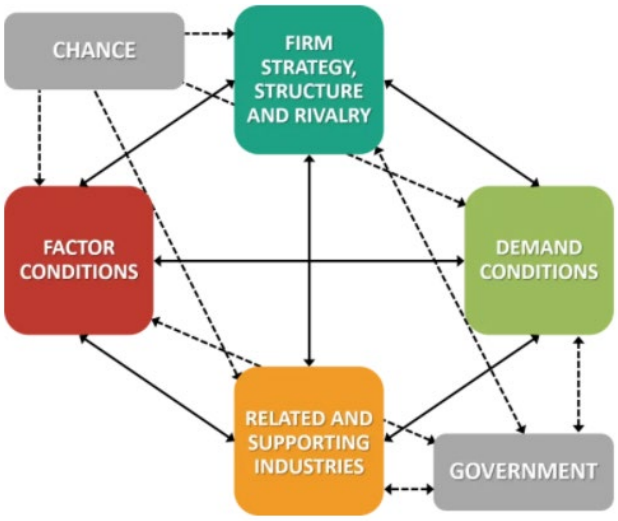


Figure: Porter's Diamond Model of National Competitive Advantage[j]

Why are some nations competitive internationally, and why are others not? How can a nation sustain its competitive advantage? Moreover, can a nation improve its competitive prospects? Michael Porter, renowned economics and strategy professor at Harvard Business School, posits a model (aptly called the "Porter Diamond") to explain that they key to national wealth and advantage is the productivity of firms and their employees *collectively*. The diamond's elements are mutually reinforcing, and each element is interdependent upon the others. Elements of his model include:

Firm strategy, structure, and rivalry

Domestic rivalry encourages competition and innovation among firms. Firms that are forced to scratch and claw ruthlessly to remain profitable at home become better able to compete abroad as well, making the U.S. more competitive internationally. America's market-oriented economy serves as a big advantage—faced with the high threat of intermodal substitutes (*e.g.*, movement of commodities by inland waterway vice truck), American firms innovate to capture greater market share, and thus profitability, from their domestic competitors—and the U.S. economy enjoys a competitive advantage against international rivals. However, free markets alone are not a panacea. Special-interest lobbying (*e.g.*, by powerful labor unions) introduce

[j] Image source: Michael Porter, "Porter's Diamond Model of National Competitive Advantage," Business-to-You, June 18, 2018, https://www.business-to-you.com/porter-diamond-model/.

market inefficiencies that make the U.S. less competitive internationally. For a holistic national strategy, the U.S. needs better synchronization between government and firms in the industry.

Factor conditions

Factor conditions include natural, capital, and human resources available in a country, and according to Porter, created factor conditions (*i.e.*, skilled labor, good infrastructure, scientific knowledge base) are more important than natural resources. Nations succeed when they are particularly good at factor creation, and here the U.S. has a mixed report card. While American infrastructure is dilapidated and overdue for repair, our air and space industries benefit from favorable business climate. Likewise, American firms paying premium wages are at a competitive disadvantage against low-labor-cost competitors like China, but our skilled labor pool and service economy drive creative science and technology solutions. Most encouraging, American universities, laboratories, and research consortia remain the envy of the modern world.

Demand conditions

Large domestic markets create more navigation and management challenges, but also more opportunities for firms to maneuver and grow market share. In global agility, the U.S. is outclassed by Asia and Europe in deep-water shipping and whole-of-nation mobilization. However, sophisticated demand requirements (particularly from the DoD) push American companies to innovate in select sectors, most notably in the air and space domains. Meanwhile, American industry titans like Amazon and UPS are lead-turning customer signals faster than their competitors, using data to predict rather than react to demand in warehousing and shipping.

Related and supporting industries

As nations depend on sovereign allies and partners to succeed, firms rely on alliances and partnerships with other companies to create additional value for customers. Here, innovation comes from higher quality inputs to production, more timely feedback from partners, and shorter lines of communication. In the U.S. global agility system, "natural" alliances among intermodal shipping industries linked by a shared goal (*i.e.*, to move goods from origin to destination as quickly and efficiently as possible) foment interdependencies, even while firms compete for the same customer. Firms also benefit most when input suppliers are global competitors (as, for example, large DoD "prime" contractors are), generating a virtuous cycle in production.

Government and chance

For Porter, the government serves as a catalyst and challenger, but not an essential ingredient for industrial competition. Government can set the conditions for marketplace competition to work and create incentives for firms to innovate. In the global agility system, U.S. firms suffer under a stifling government-imposed regulatory environment; then again, the government's deep research and development and capital investment pockets serve as a "war chest" for American firms. Finally, chance plays a role in global competition, as exogenous events like war, floods, rising sea levels, and other natural and man-made disasters affect international shipping lanes, ports, and overland transportation infrastructure in seemingly random ways.

Appendix B: Abbreviations

AAPA	American Association of Port Authorities
AI	Artificial Intelligence
ASCE	American Society of Civil Engineers
CCP	Chinese Communist Party
COVID-19	Coronavirus
CRAF	Civil Reserve Air Fleet
CRRC	China Railway Rolling Stock Corporation
CSX	Chessie Seaboard Consolidated
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
DoT	Department of Transportation
FAA	Federal Aviation Administration
GDP	Gross Domestic Product
HMTF	Harbor Maintenance Trust Fund
IoT	Internet of Things
IWTF	Inland Waterways Trust Fund
LTL	Less-than-Truckload
MARAD	Maritime Administration
ML	Machine Learning
MSC	Military Sealift Command
NAICS	North American Industry Classification System
STRACNET	Strategic Rail Corridor Network
TRANSCOM	U.S. Transportation Command
TSA	Transportation Security Administration
U.S.	United States
ULA	United Launch Alliance
UNOOSA	United Nations Office for Outer Space Affairs
USMM	U.S. Merchant Marine
USSF	U.S. Space Force

The Last Appendix
Thank you for reading this far
Now some fun haikus

The U.S. prepares
For disruptive disorder
Infrastructure old

Agility wins
Competitive advantage
Industry adapts

The nation secure
Trade policies updated
Our work is finished
-- Jennifer Nolan

Deep-water shipping
Wallenius Wilhelmsen
Is the right answer
--Jim Reynolds

Inland waterways
Key to America's growth
Now they need some help
--Dana Canby

Truckers roll along
Twinkies, jerky, Cherry Coke
Road necessities

Yellow, Dominion
FedEx, XPO loggies
Top U.S. movers
--Rachel Dunlap

[k]

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