Assessment of the Jones Act Waiver Process on Freight Transportation Networks Experiencing Disruption

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ACADEMIC ABSTRACT

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Much of the critical infrastructure resilience and security literature focuses on the "hardening" of physical infrastructure, but not the relationship between law, policy, and critical infrastructure. Traditional views of transportation systems do not adequately address questions of governance and behaviors that contribute to resilience. In contrast, recent development of a System of Systems framework provides a conceptual framework to study the relationship of law and policy systems to the transportation systems they govern.

Applying a System of Systems framework, this research analyzed the effect of relaxing the Jones Act on freight transportation networks experiencing a disruptive event. Using WebTRAGIS (Transportation Routing Analysis GIS), the results of the research demonstrate that relaxing the Jones Act had a marginal reduction on highway truck traffic and no change in rail traffic volume in the aftermath of a disruption. The research also analyzed the Jones Act waiver process and the barriers posed by the legal process involved in administration and review for Jones Act waivers. Recommendations on improving the waiver process include greater agency coordination and formal rulemaking to ensure certainty with the waiver process.

This research is the first in studying the impact of the Jones Act on a multimodal freight transportation network. Likewise, the use of the System of Systems framework to conceptualize the law and a critical infrastructure system such as transportation provides future opportunities for studying different sets of laws and policies on infrastructure. This research externalizes law and policy systems from the transportation systems they govern. This can provide policymakers and planners with an opportunity to understand the impact of law and policy on the infrastructure systems they govern.

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GENERAL AUDIENCE ABSTRACT

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To my parents, Wendy and Sheldon Fialkoff

Who provided me the love, wisdom, and more than a few Lego bricks for me to build my path

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Acronyms and Abbreviations

Burlington Northern & Santa Fe Railway	BNSF
Canadian National Railway	CN
Canadian Pacific Railway	CP
Center for Transportation Analysis	CTA
Commodity Flow Survey	CFS
Confidential Carload Waybill Sample	CCWS
CSX Transportation	CSX
Federal Highway Administration	FHWA
Federal Motor Carrier Safety Administration	FMCSA
Federal Railroad Administration	FRA
Freight Analysis Framework	FAF
Geographic Information Systems	GIS
Graphical User Interface	GUI
Kansas City and Southern	KCS
Mainline Classification	MLC
Maritime Administration	MARAD
Maritime Transportation System	MTS
Maritime Transportation System Recovery Unit	MTSRU
National Cooperative Freight Research Program	NCFRP
National Cooperative Highway Research Program	NCHRP
Norfolk International Terminal	NIT
Norfolk Southern	NS
Oak Ridge National Laboratory	ORNL
Port Authority of New York and New Jersey	PANYNJ
Relative Root Mean Square Error	RRMSE
Standard Point Location Code	SPLC
System of Systems	SoS
Transportation Research Board	TRB
Transportation Routing Analysis GIS	TRAGIS/WebTRAGIS
U.S. Coast Guard	USCG
U.S. Customs and Border Protection	CBP
U.S. Department of Energy	DOE
U.S. Department of Homeland Security	DHS
U.S. Department of Transportation	DOT
Union Pacific	UP

Glossary

Autonomy: The ability to be free to pursue a purpose, an attribute within a System of Systems

Autopoiesis: A System capable of maintaining itself

Belonging: The ability for constituent systems to decide whether to participate in a System of Systems

Cabotage: The right to operate sea, air, or other transport services within a particular territory

Confidential Carload Waybill Sample: A stratified sample of carload waybills for all U.S. rail traffic submitted by those rail carriers terminating 4,500 or more revenue carloads annually maintained by the Surface Transportation Board

Connectivity: Ability for constituent systems to connect, through either networks or other means

Critical Infrastructure: Systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters

Diversity: Constituent systems performing various functions that make them unique from other participating systems

Emergence: The ability to develop new capability or tendencies based off the interaction of constituent systems

Freight Analysis Framework: A database of freight movement among states, major metropolitan areas, and international zones by all modes of transportation within the United States

Haulage Right: An agreement between railroad companies that separate marketing and operating functions. The railroad receiving haulage rights gets control of marketing.

HIGHWAY: Legacy system to TRAGIS for highway routing

Impedance: Modifies the distance parameters in the shortest path algorithm so that the objective function for each of the modes is not strictly shortest path, reflects operational attributes for moving on a particular mode

Institution: Structures, rules, norms and routines that operate across jurisdictions

Interchange: Location where a transfer of freight and/or equipment occurs in the railroad network. An interchange can be located at a junction, a physical location within the railroad network

INTERLINE: Legacy system to TRAGIS for railway and waterway routing

Link: Lines that connect nodes. In transportation, links can represent roads, railroads, waterways

Managerial Independence: The Systems being assembled come together as a matter of circumstance, but can exist independently should that circumstance change

Modal Flexing: The ability for other modes to pick up the slack if a mode suffers damage or disruption in operation

Monocentric Institutions: Authority is concentrated in one institution for purpose of decision-making

Nested Complexity: A relationship existing between a physical domain embedded within an institutional domain

Node: Intersection of links. In transportation, nodes can represent stations, intersections, interchanges, and /or ports

Operational Independence: The system must be able to operate independent from the System of System it supports

Polycentric Institutions: Multiple power centers involved in decision-making

Resilience: Ability to resist, absorb, and adapt to disruptions and return to normal functionality

Short Sea Shipping: The movement of cargo and passengers mainly along a coast

Standard Point Location Code: A six to nine digit numeric code assigned to all stations registered by rail carriers and specify physical location of a station

System Architecture: Defines structure, behavior, and views within a system

System of Systems: The viewing of multiple, dispersed, independent systems in context as part of a larger, more complex system

System: A group of interacting components that form a complex and unified whole

Trackage Right: A tenant railroad is solely responsible to the shipper for providing transportation service over the joint facility and for loss and damage to the freight

Chapter 1: Introduction

1.1 "Disasters have Consequences"

Modern industrial societies are witnessing their infrastructure evolving to become more complex, interconnected, and interdependent than previously observed or conceived. Given such complexity and interdependence, a failure in one infrastructure system could lead to a cascading failure across infrastructures depending on the circumstances presented. This complexity presents challenges to planners and policymakers who are responsible to prepare for and respond to catastrophic events. From the perspective of the policymaker, this raises the question of whether legal and policy frameworks are adequate to assure resilient infrastructures in the face of emerging threats, natural or human induced. While much emphasis has been placed on the physical hardening of infrastructure, there has been limited study of the explicit effects of law and policy interventions on infrastructures and how such measures affect critical infrastructure resilience.

When considering freight transportation systems, one of the first questions in the aftermath of a disruption is how much of the transportation infrastructure is still operational. Over the last decade, the resilience and critical infrastructure discourse has allowed for a reappraisal of the concept of resilience, its use, and its application to other disciplines. In the context of freight transportation resilience, emerging research has broadened the focus of resilience from physical readiness of the networks to include the institutional, managerial, and user readiness in the aftermath of a disruptive event. In contrast to passenger transportation, freight transportation networks are one part of a greater supply chain, where the decision to move goods on a particular mode is a business decision.

Freight transportation moves America's goods and is the backbone to the U.S. economy. According to the Federal Highway Administration (FHWA) (Strocko *et al.* 2014), approximately nineteen billion tons of freight traveled through the United States in 2012, worth approximately seventeen trillion dollars (U.S.). Hurricane Sandy also occurred in 2012, a Category 2 hurricane that affected the Eastern Seaboard of the United States and the Caribbean (Blake *et al.* 2013). Because of Superstorm Sandy, twenty percent of commercial trucking in the Northeast stalled in the week after the storm, amounting to a loss of $140 million dollars per day (Henry *et al.* 2013).

In terms of damage to the freight transportation networks, Hurricane Sandy devastated road and rail infrastructure in the affected areas. Specific disruption to freight operations occurred in the Northeast, with the closure of the Port of New York and New Jersey and the damage to surrounding road and rail infrastructure. Approximately fifteen-thousand containers and nine-thousand automobiles bound for the Port of New York and New Jersey diverted to the Port of Norfolk in Virginia and the Port of Halifax in Nova Scotia (Flynn, 2015; Lombardi, 2014). Given these diversions, supply chain managers, port operators, and transportation operators needed to consider increased traffic through facilities and reconfigure overall shipments to adapt to the changes resulting from the port closure in New York. While the physical damage and disruption resulting from the storm were on full display, Hurricane Sandy and the closure of the Port of New York and New Jersey brought to light the need to evaluate the effectiveness of existing shipping laws and procedures at the time of a crisis. This research focuses on understanding the effect of laws on infrastructure resilience, in particular, the provisions of the Merchant Marine Act of 1920, more commonly known as the Jones Act.

Under the operative provisions of the Jones Act, vessels not built in the United States and not crewed by a requisite number of U.S. citizens cannot participate in coastwise trade, the movement between two points, within territorial waters of the United States. Although a waiver procedure exists to permit excluded vessels from engaging in coastwise trade, the waiver is granted only under strict circumstances. In the aftermath of Hurricane Sandy, various observers commented on the impact of the Jones Act and questioned whether its relaxation during Hurricane Sandy would facilitate recovery for freight movement. While the focus here is on the effect of relaxing the Jones Act on freight transportation resilience, a larger question presents itself; what is the relationship between the law and policy systems and the infrastructure systems they govern?

1.2 Problem Statement and Background

This dissertation asks the question to what extent law and policy impacts networked infrastructure during disruptions. Specifically, what effect did the Jones Act and the restriction on short sea shipping have on rail and road networks that had to compensate for additional traffic because of the Port of New York and New Jersey closure? The impact of law and policy interventions on transportation networks is a largely understudied area, especially during disruptions and the role of law and policy in fostering resilient freight transportation systems.

Conceptually, the focus on law and policy drivers presents challenges to a traditional view of transportation as a system. Insofar as transportation infrastructure is part of the environment and responds to changes in its surroundings, law and policy are “environmental” factors (Rinaldi, Peerenboom, Kelly, 2001). With recent research describing the complexities in transportation and the emerging field of transportation resilience, the traditional systems view of transportation is inadequate in explaining the role of institutional, managerial, and administrative elements. In contrast, contemporary development of the System of Systems (SoS) framework enables more sophisticated representation of complex systems (Maier, 1998). Likewise, the System of Systems framework and its theoretical underpinning accounts for and explains the role of emergent behaviors and how they lead to resilience. To show the various relationships discussed throughout the dissertation within the System of Systems framework, Figure 1.1 will be used throughout the dissertation to represent various relationships between the systems discussed.

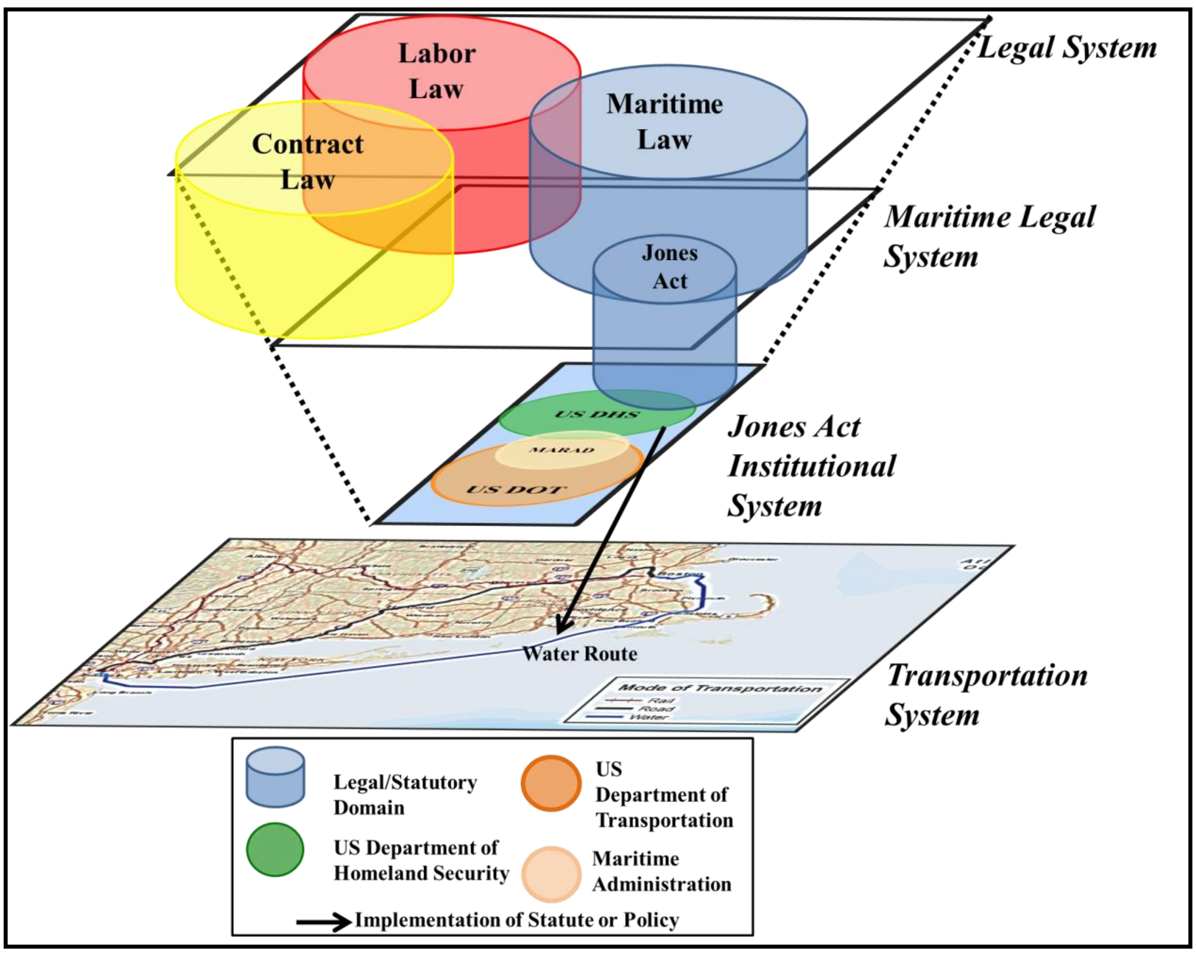

Figure 1.1: Conceptual framework for dissertation
Credit: M. Fialkoff (2017)

Over the past thirty-five years, Oak Ridge National Laboratory (ORNL) developed transportation networks to study the movement of Spent Nuclear Fuel (SNF) and High Level

Radioactive Waste (HLRW) (Peterson, 2016). The research led to the development of highly detailed representations of the highway, railway, and waterway networks in the United States. Over time, legacy software systems focused on routing analyses were consolidated into one, web-based tool known as Transportation Routing Analysis GIS (WebTRAGIS). Although WebTRAGIS supports current U.S. Department of Energy (DOE) programmatic objectives for routing hazardous materials within the United States, the tool is capable of freight diversion routing (Georgia Tech Research Corporation *et al.* 2012). In addition to WebTRAGIS, this dissertation uses the Freight Analysis Framework (FAF) and the Confidential Carload Waybill Sample (CCWS) to represent freight flow over the routes generated by WebTRAGIS. This process requires the datasets be geo-spatially linked to the ORNL transportation networks such that the data can be "flowed" over the highway and railway networks. The procedure developed for linking the datasets to the transportation networks is discussed in Chapters 4 Chapter 5.

By using these datasets, it is possible to study the effect of law on transportation systems experiencing disruption. This can provide insight for policymakers for proper analysis for changing existing laws and policies that may be acting as a barrier to recovery for these transportation networks. In contrast to previous work that has merely speculated on the impact of relaxing the Jones Act under disruptive circumstances, this dissertation leverages geospatially enabled data and provide legal analysis to address the over-arching question: *what effect does the law have on the transportation systems they govern?*

1.3 Objectives of the Dissertation

This dissertation sets out three objectives:

1.3.1 Objective 1

Establish a conceptual and theoretical framework to study the relationship between law and policy with respect to critical infrastructure resilience, particularly in the domain of freight transportation.

The role of law and policy in infrastructure governance, particularly in the context of critical infrastructure resilience has largely been understudied at the conceptual level. To the extent that previous work implicitly included law and policy within "environmental" factors that infrastructure responds to, this view does not externalize law and policy and its effects on infrastructure. Similarly, the traditional systems view of transportation neither adequately represents the role of law and policy in transportation governance nor does a systems view account for emergent behaviors that lead to resilience.

In contrast, over the last twenty years, the development of the System of Systems framework provides a more sophisticated conceptual framework to study questions of complex and interdependent systems. Compared to traditional Systems Thinking, a System of Systems framing of transportation recognizes the autonomy and independence of constituent systems (legal system, transportation system), but also their connectivity and the emergent behaviors that result from their interactions. Chapter 3 focuses on further elaborating on the traditional systems view, its shortcomings, and the evolution and development of the System of Systems framework, particularly as it applies to transportation, resilience as an emergent behavior, and the law as a system that is part of the overall larger System of Systems framework.

1.3.2 Objective 2

The application of novel quantitative techniques to study how the law and policy interventions affect transportation networks experiencing disruption.

In the aftermath of Hurricane Sandy, various studies described the effect of Hurricane Sandy on the freight transportation network, particularly the disruption caused by the closure of the Port of New York and New Jersey and the diversion of freight traffic to the Port of Norfolk. Significant damage to rail and road infrastructure surrounding the Port of New York and New Jersey slowed down recovery for transportation networks surrounding the Port (Southworth *et al.* 2014). With surrounding infrastructure damaged and the Port of New York and New Jersey reopened within a matter of days after the storm, stranded cargo at the Port could not move, slowing down delivery of goods to customers (Smythe, 2013). As Chapter 2 describes in further detail, the impact of the storm caused disruptions that rippled through the U.S. economy and focused critique for a slow transportation recovery on the Jones Act and the inability to gain waivers to permit short sea shipping between U.S. ports.

Currently, no quantitative analysis evaluates the impact of relaxing the Jones Act. A recent review of recovery efforts in the aftermath of Hurricane Sandy suggested that High Performance Computing and Geographic Information Science are tools that can improve real-time decision-making tools for reviewing policy and legal decisions (Flynn, 2015). In July 2016, the Transportation Research Board (TRB) initiated a call to study the spatial, temporal, and institutional response strategies to freight disruptions. The report sought to address these challenges and provide recommendations for developing resilient freight transportation that address not just the physical readiness of freight transportation, but also the institutional and regulatory support that is needed (Rogers, 2016).

Given the timeliness of this call by the Transportation Research Board and the lack of quantitative analysis as it relates to the impact of the Jones Act, this dissertation uses the case of Hurricane Sandy to analyze the effects of the Jones Act on freight transportation networks. Following the recommendations provided by Flynn (2015), this dissertation uses the WebTRAGIS tool to evaluate the impact of relaxing the Jones Act on the highway and railway networks affected by the storm. As part of this analysis, the Freight Analysis Framework and Confidential Carload Waybill Sample were geospatially linked to the transportation networks developed by ORNL such that the routes generated by the TRAGIS routing engine represent freight flow moving over those particular segments of the network. The procedure for linking the FAF and CCWS to the transportation networks developed by ORNL is discussed in Chapters 4 and 5, with the results from the three scenarios generated reported in Chapter 6.

1.3.3 Objective 3

Evaluate existing statutory and regulatory processes as they relate to the Jones Act waiver process and provide critique and recommendations on the existing framework for reviewing Jones Act waivers.

Since its passage in 1920, the Jones Act has served as the cornerstone for U.S. maritime law. It provides basic rights to “maintenance and cure” to injured seaman and governs cabotage laws for U.S. maritime shipping. While the original purpose of the cabotage provisions of the statute was protecting American national security interests and to ensure a merchant marine fleet in the aftermath of World War I, over time, the analysis and rationale used by the courts in evaluating Jones Act issues shifted to economic protectionism. In a post 9/11 national security context, the Jones Act has been viewed as a tool in protecting U.S. shores and territorial waters from terrorist threat (Gouré 2016a; 2016b). Calls for repeal, review, and reform of the Jones Act have been met with skepticism, if not outright criticism (Yost, 2013; Leback and McConnell, 1983).

The problem with contemporary analysis of the Jones Act is the focus on the economic and political implications and less on operational impacts of the provisions of the act. The study of the Jones Act wavier process and its effects on freight transportation resilience provides an opportunity to explore the role of law and policy on fostering resilience in the infrastructure context. Contemporary research on law and resilience has led to the conclusion that the Western Legal System acts more as a barrier to resilience because of its mal-adaptive tendencies (Gunderson and Arnold, 2013). Chapter 3 explores how Institutional Theory and Legal Reductionism has led to an ossified Legal System that is not adaptive to situations and leads to linear thinking, with limited feedback loops available for change. From this perspective, Chapter 7 examines the provisions of the Jones Act waiver process, focusing on the 2015 decision *Furie Operating Alaska, LLC v. U.S. Department of Homeland Security*, the lack of agency standards for assessing Jones Act waivers, and recommendations for changing the process going forward.

1.4 Scope of the Dissertation

To study the effect of the Jones Act on networked infrastructure, this dissertation uses Hurricane Sandy as a case study to analyze the effect of relaxing the law on the highway and railway networks affected by the storm. Hurricane Sandy was selected as the case study for this dissertation because of the amount of information available relating to freight movement in the aftermath of the storm. In contrast to other storms such as Hurricane Katrina and Hurricane Rita, qualitative research on Hurricane Sandy recovery provided more information on freight diversions and the number of containers diverted because of the storm (Flynn, 2015; Lombardi, 2014; Southworth *et al.* 2014).

From an analytical perspective, the type of cargo rerouted to the Port of Norfolk also made Hurricane Sandy an optimal case for analyzing the Jones Act waiver process. From reports on the impact of Hurricane Sandy from the perspective of transportation, approximately 6,500 containers originally destined for New York traveled to Norfolk (Flynn, 2015). In contrast to other commodities such as break bulk, oil and petroleum products, or natural resources such as timber, containers are discrete loads that can be converted into trucks or trains based on the data currently available.

In contrast to Hurricane Katrina and Rita that affected the Gulf Coast, the primary affected commodity was oil, which is more likely to receive a Jones Act waiver than general container freight. Hurricane Sandy is one of the most recent storms where the Jones Act was not relaxed for general cargo, but was subsequently relaxed for home heating oil because of shortages in the affected areas in the aftermath of the storm. Disasters differ and follow dissimilar trajectories with their effect on transportation systems. While the results indicate that relaxing the Jones Act would not change rail traffic patterns or significantly decrease the number of trucks on the highway, not all disasters behave the same way.

On a conceptual level, this research develops a framework to study law and policy interventions and their relationship to critical infrastructure resilience. The focus on the Jones Act waiver process and critique of the vague standards for assessing Jones Act waivers is not an indictment of the entire American Administrative State; rather it provides a discrete example of where reform is possible. The results from studying the Jones Act and its waiver process in the context of a disaster can provide agencies and scholars with policy recommendations for how to better coordinate amongst multiple agencies in a crisis and describe formal rulemaking procedures to create certainty for the waiver process. Chapter 7 provides further guidance on the impact of increased agency coordination and the potential for formal rulemaking in this area.

In relation to the quantitative analysis conducted in this study, it is important to acknowledge at the outset that WebTRAGIS is a strategic planning tool that provides a macro-scale view for the research questions presented. In comparison to a tactical or operational approach to freight planning, a strategic approach allows for research and analysis at the regional level (Crainic and Laporte, 1997). Because Hurricane Sandy affected a large geographic area, a strategic tool such as WebTRAGIS provides sufficient resolution to study the research questions asked in this dissertation. In terms of procedures that link datasets to transportation networks, as described in Chapters 4 and 5, WebTRAGIS is only one tool amongst many available for this type of analysis. The procedures described are interoperable to other networks and other routing engines. Chapter 8 discusses future research opportunities that focus on local effects of increased freight traffic in the Norfolk area, rather than the large geographic area studied in this dissertation.

1.5 Structure of the Dissertation

The structure of the dissertation provides a framework with which to evaluate the questions presented and provide analysis that speaks to both policymakers and planners, while illustrating the actual impact of a particular law on networked infrastructure from an engineering perspective. In balancing these goals, the structure of the dissertation addresses the objectives discussed in Section 1.3 and is illustrated in Figure 1.2.

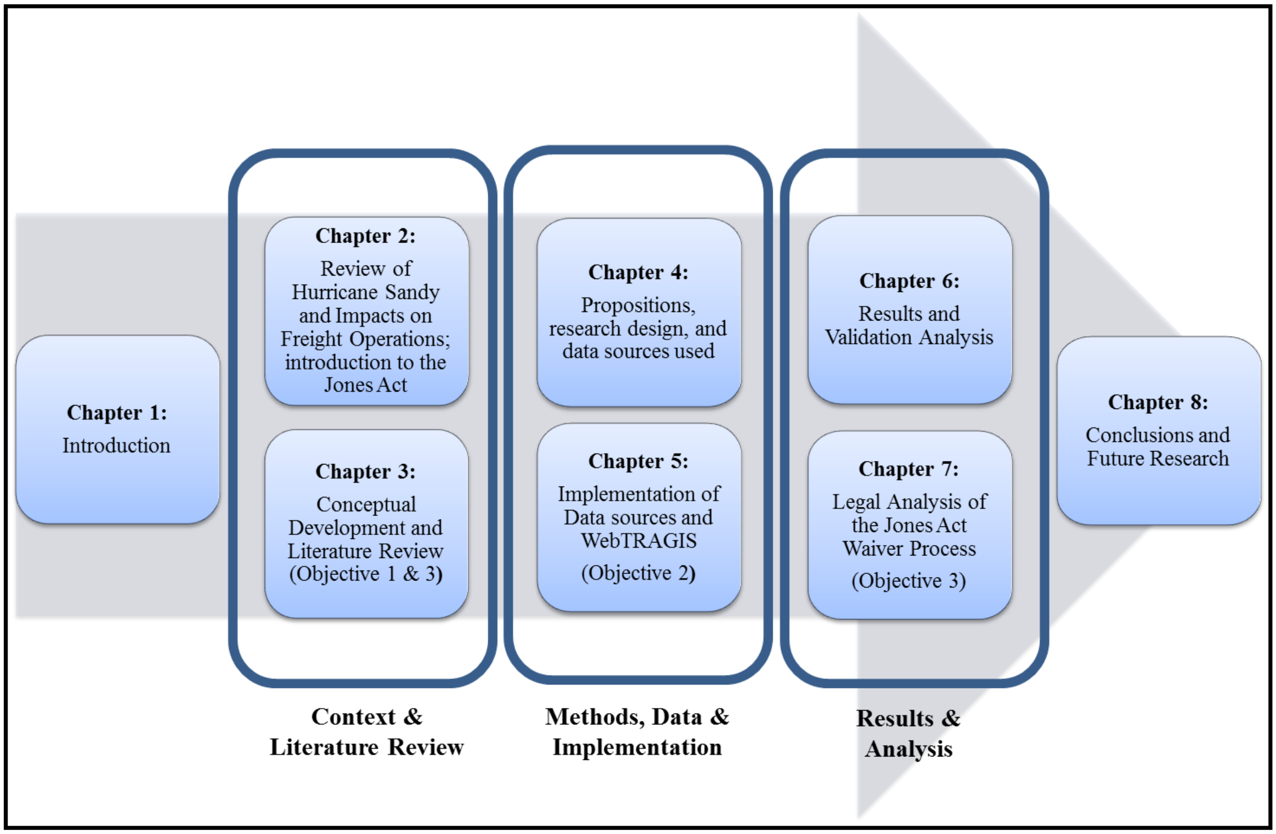

Figure 1.2: Structure of the dissertation
Credit: M. Fialkoff (2017)

Chapter 2 provides a description of the events that occurred during and after Hurricane Sandy. The chapter provides a foundation from which the state of the freight transportation infrastructure during and in the immediate aftermath of the storm can be understood. It also reviews the findings on the recovery efforts in the freight transportation sector and the shortcomings that were observed, particularly in the maritime transportation sector and in relation to intermodal connectivity. In this chapter, the Jones Act and the waiver process are introduced. Using the example of Hurricane Sandy and its effect on the freight network with the closure of the Port of New York and New Jersey, the impact of the Jones Act restriction illustrate how the law acted as a barrier to freight recovery.

Chapter 3 addresses the complexity in trying to understand the relationship between the legal and policy systems and the infrastructure systems they govern. The chapter describes the current view of transportation systems thinking and introduces the System of Systems framework, comparing its ability to account for complexity between multiple systems. The chapter also introduces the concept of diversion analysis as a method to study transportation networks experiencing disruption.

Chapter 4 operationalizes the problem. In particular, it describes the three scenarios developed to study the Jones Act and its effect on freight transportation networks. The chapter brings together the research questions developed in Chapters 2 and 3 and describe the datasets used in this research. The discussion focuses on the preparation of the Freight Analysis Framework for use with WebTRAGIS. Chapter 4 concludes with a brief discussion of the rail traffic analysis used in this research. Chapter 5 describes the TRAGIS routing engine, the transportation networks used, and the process for converting the Confidential Carload Waybill Sample into routable data for the TRAGIS routing engine.

Chapter 6 provides an analysis of the routes produced by WebTRAGIS and the rail traffic analysis. The results focus on the highway and railway outputs generated by WebTRAGIS. In general, relaxing the Jones Act for the highway and railway networks did not change the rail traffic patterns and only marginally reduced the number of trucks on the highway. The chapter also discusses a validation analysis of the accuracy of the WebTRAGIS routes in comparison to observed routes. For both the highway and railway routes selected for the validation analysis, the results indicate the routes generated by WebTRAGIS were accurate to the observed routes generated by independent databases.

While Chapter 6 focused on the results from the quantitative analysis, Chapter 7 analyzes the Jones Act waiver process using a more traditional legal analysis. Jones Act waiver jurisprudence is limited, although the recent *Furie* decision from the Federal District Court in Alaska provides insight into the lack of guidance or standards for Jones Act waiver claims. The court in *Furie* determined that Jones Act waiver decisions are unreviewable by Article III courts as there is no standard of law for the courts to apply. The chapter analyzes how this type of decision perpetuates institutional ossification. The chapter concludes by recommending reforms to the waiver process, including greater agency coordination for making Jones Act waiver decisions and suggesting formal rulemaking to reduce the ad hoc nature in Jones Act waiver decisions.

Finally, Chapter 8 provides a summary of the research undertaken and highlights the results from the study. Although the results indicate that relaxing the Jones Act would not have a significant impact on the freight transportation network, the results indicate that further investigation could help to understand the effects on a local level, not a regional level. Future micro-simulation of the local highway network surrounding Norfolk would provide further insight into the effects of the Jones Act at a local level. Future research for the Jones Act waiver process could include the impact of formal rulemaking and the role of *Chevron* when multiple agencies are involved in rulemaking for Jones Act waivers.

1.6 References

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Chapter 2: Hurricane Sandy and its impact on Freight Transportation

2.1 Introduction

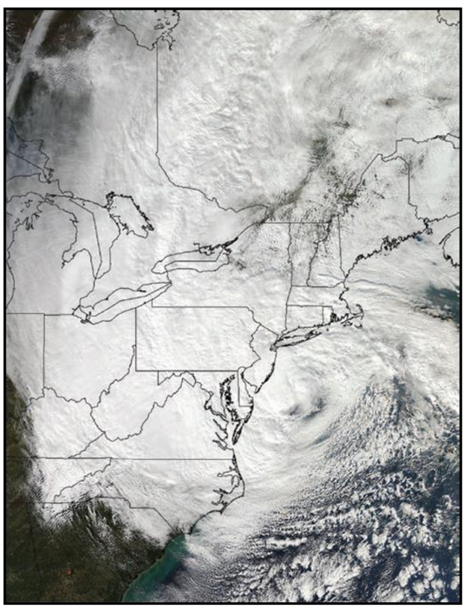
This chapter presents a contextualized example of the disconnect between law and the infrastructure systems they govern, namely, the Jones Act restriction on short sea shipping and the impact on the freight networks affected by Hurricane Sandy. The damage caused by Hurricane Sandy affected multiple infrastructure systems, among them, the transportation of goods within the Mid-Atlantic States. In the aftermath of the storm, reports commented on the Jones Act, claiming the Statute was a barrier to recovery for the freight transportation system (Flynn, 2015; Southworth *et al.* 2014). The restriction on coastwise trade, the movement of foreign vessels between two coastwise points in the United States proved problematic for cargo diverted to the Port of Norfolk and stranded cargo in the Port of New York and New Jersey.

In the case of the Port of New York and New Jersey, damage to the surrounding road and rail infrastructure isolated the Port from moving freight out of the facility once the storm passed. Damage to road infrastructure and drayage vehicles with flooding of rail yards kept the Port from restarting intermodal operations. On the other hand, traffic diverted to the Norfolk International Terminal (NIT) at the Port of Norfolk saw an increase in container and vehicle thru-put. Because of this, more chasses, rail cars, and trucks needed to be available to get the freight out of NIT for inland transit. Although U.S Customs and Border Protection (CBP) gave a diversion order, the Jones Act was not suspended for general freight; rather it was suspended when petroleum and home heating fuel became scarce in the Northeast following the storm.

This chapter describes the events of Hurricane Sandy, with a focus on how the storm affected freight transportation operations leading up to the storm and in the immediate aftermath. From there, the chapter will turn to previous reports that studied freight recovery during Hurricane Sandy and the recommendations provided by each of the reports. Finally, the chapter provides a brief introduction to the relevant provisions of the Jones Act, primarily, those discussing the restrictions on short sea shipping and the waiver process. The events of Hurricane Sandy, particularly in the case of freight transportation and the Jones Act highlights the complexity involved with understanding the relationship between law and policy and the infrastructure systems they govern. As the events following Hurricane Sandy unfolded, decisions made by planners and policymakers relating to restricting maritime transportation did not account for the downstream impacts on modes bearing additional pressures.

2.2 Tracking Hurricane Sandy

Hurricane Sandy has been described as a "multi-storm event," affecting the East Coast of the United States and the Caribbean in October 2012. Prior to reaching the shores of the United States, the origins of the storm tracked back to a tropical wave off the West Coast of Africa in early October 2012 (Blake *et al.* 2013). As the storm moved east towards Jamaica and the Caribbean, it picked up speed and intensity, the eye of the storm stabilized and approximately ninety miles south of Kingston, Jamaica (Wakeman, 2013). From there, the storm moved north towards the southeastern coast of the United States, reaching peak wind gusts of ninety-seven miles per hour, as illustrated in Figure 2.1 (Wakeman, 2013). Prior to making landfall in Brigantine, New Jersey, on October 29, 2012, the storm began to weaken to sustained wind speeds of eighty miles per hour.



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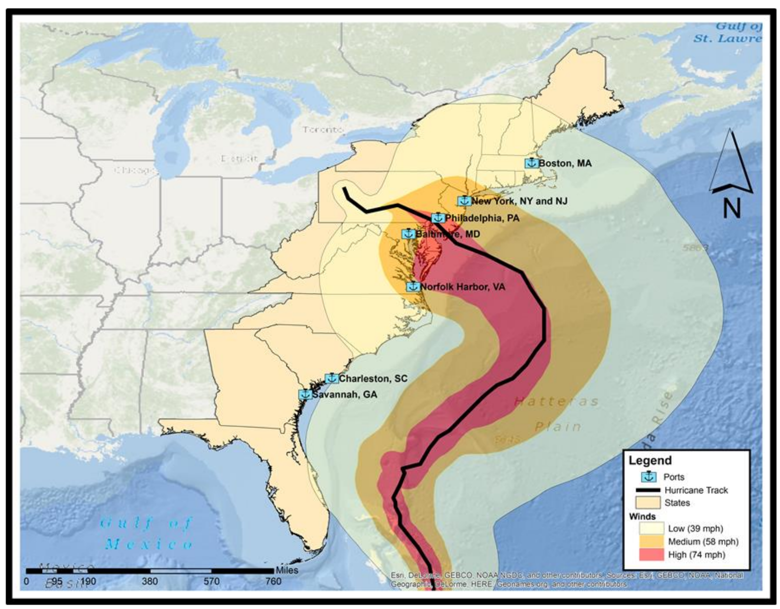

b

Figure 2.1: Hurricane Sandy
a. NASA imagery of Hurricane Sandy; b. Storm track for Hurricane Sandy
Source: a. Southworth et al. (2014) (with permission); b. Fialkoff et al. (2017)

In the Northeast, the impact of the storm surge and high waves caused damage across several states. States heavily affected by storm surge included Connecticut, New York, and New Jersey, with the South Shore of Long Island, New York City, and the northern and central coastlines of New Jersey severely flooded (Sharp, 2012).

Storm surge caused by Hurricane Sandy was exacerbated by the fact that the storm made landfall around the same time a full moon occurred, increasing tidal effects in coastal areas. For example, at buoy 44025, located thirty-five miles south of Islip, Long Island, wave heights topped out at 31.6 feet, exceeding the previous recorded high of 30.5 feet set in December 1992 (Wakeman, 2013). The buoy at the entrance of New York Harbor recorded wave heights of 32.3 feet, exceeding the previous high of 26 feet recorded during Hurricane Irene (Wakeman, 2013). The tide gauges at the Battery in Manhattan and at Bergen Point West Reach on Staten Island recorded tides at 9.0 and 9.53 feet above the Mean Higher High Water mark, respectively (Wakeman, 2013). At Sandy Hook, New Jersey, tide heights were marked at 8.57 feet above normal tide levels. The station subsequently failed during the storm and stopped recording tide levels (Wakeman, 2013).

2.3 Impacts of Hurricane Sandy

The following sections describe the impact of the storm from four perspectives:

- general impacts of the storm for the Mid-Atlantic States,
- impact of the storm on the Port of New York and New Jersey,
- impact on the Port of Virginia, specifically, the Port of Norfolk and the Norfolk International terminal, and
- overall impact on the freight networks

While Section 2.3.1 broadly discusses general impacts of Hurricane Sandy, other studies have been conducted that focus on Hurricane Sandy's impacts and subsequent recovery, including work by the Department of Energy (2013), Department of Housing and Urban Development (2013), the Urban Land Institute (McIlwain, 2013), and Flynn (2015).

2.3.1 General Impacts

Damage caused by Hurricane Sandy, also known as Superstorm Sandy, was severe. Most of the damage occurred across the Mid-Atlantic States, with Connecticut, New York, and New Jersey being the hardest hit. Transportation, energy, communications, water, and health systems were paralyzed, either because they were damaged or did not have power to function. Cleanup and cost of recovery caused by the hurricane has been calculated to approximately sixty-eight billion dollars (U.S.) (Flynn, 2015).

Multiple infrastructure systems were disrupted during Hurricane Sandy. Across passenger transportation systems, damage resulted in stranded drivers and commuters. Because of the storm, approximately 4.2 million drivers, 8.5 million bus passengers, and 1 million airline passengers were stranded because of damage and flooding to airports, roads, and commuter transit (Flynn, 2015). Superstorm Sandy caused electrical outages for 8.66 million people across twenty-states, including Washington D.C. (U.S. DOE, 2013). Within the Energy sector, damage included flooded marine terminals and refineries and damaged infrastructure associated with Liquefied Natural Gas (U.S. DOE, 2013). The damage in the Energy Sector caused cascading failures across multiple, connected infrastructures. The interdependency of infrastructures was illustrated in downstream impacts, for example, six hospitals in New York were evacuated when the back-up generators failed to turn on (Flynn, 2015).

2.3.2 Impacts on the Port of New York and New Jersey

Before discussing the impacts of Hurricane Sandy on the Port of New York and New Jersey, it is necessary to provide a geographic and operational context for the facilities associated with the Port. The Port itself is a multi-terminal facility dotting both the New York and New Jersey sides of New York Harbor. The ownership structure for the facilities and terminals for the multiple facilities is complex (Smythe, 2013). The bi-state, Port Authority of New York and New Jersey (PANYNJ) has a landlord type arrangement with companies that use the various terminals. Some facilities and refineries are wholly owned and operated by private companies. In October 2012, the Port of New York and New Jersey was the third largest port in the United States and the largest on the East Coast (Smythe, 2013).

The various facilities that comprise the overall Port handle a variety of cargoes, ranging from bulk and break bulk to oil, vehicle roll on and roll capability, container services, and passenger traffic. Wakeman (2013) describes New York Harbor as “the largest petroleum hub in the Northeast, with bulk storage exceeding seventy-five million barrels.” The facilities that comprise the Port of New York and New Jersey are represented in Table 2.1.

Table 2.1: Terminals of Port of New York and New Jersey

New York Container Terminal	Global Terminal and Container Services
Red Hook Container Terminal	Maher Terminal
APM Terminal	Port Newark Container Terminal

Source: Southworth et al. (2014)

As Figure 2.2 highlights, these facilities are dispersed across New York Harbor, with various terminals having different connectivity to different parts of the freight transportation network in the Northeast.

Figure 2.2: Facility layout of the Port of New York and New Jersey
Source: Southworth et al. (2014) (with permission)

New York Harbor was in the direct path of the storm and its storm surge. Initial reports indicated that numerous facilities within the Port were damaged, particularly those facilities located in Arthur Kill, more commonly known as Staten Island Sound, and those facilities located in Newark Bay (Wakeman, 2013). Although the Port suspended operations on October 28, 2012, cargo that was still at the Port suffered damage, along with infrastructure that supported port operations.

Outside the Port, other surface transportation modes suffered severe damage because of the storm. The CSX Kearney rail yard, a major regional intermodal facility was flooded with four feet of water, causing damage to electrical relays, chasses, and other vehicles (Southworth *et al.* 2014). Other Class I rail terminals such as Norfolk Southern's (NS) Croxton and ERail terminals did not experience as much damage as to the Kearney yards, although rail relays short-circuited or flooded. The Greenville yard lost a rail barge float that sank and a transfer bridge was destroyed (Southworth *et al.* 2014; Strauss-Wieder, 2014). In addition to the damaged rail infrastructure, security fences surrounding facilities obstructed right of ways and drayage access roads were littered with debris, as illustrated in Figure 2.3.

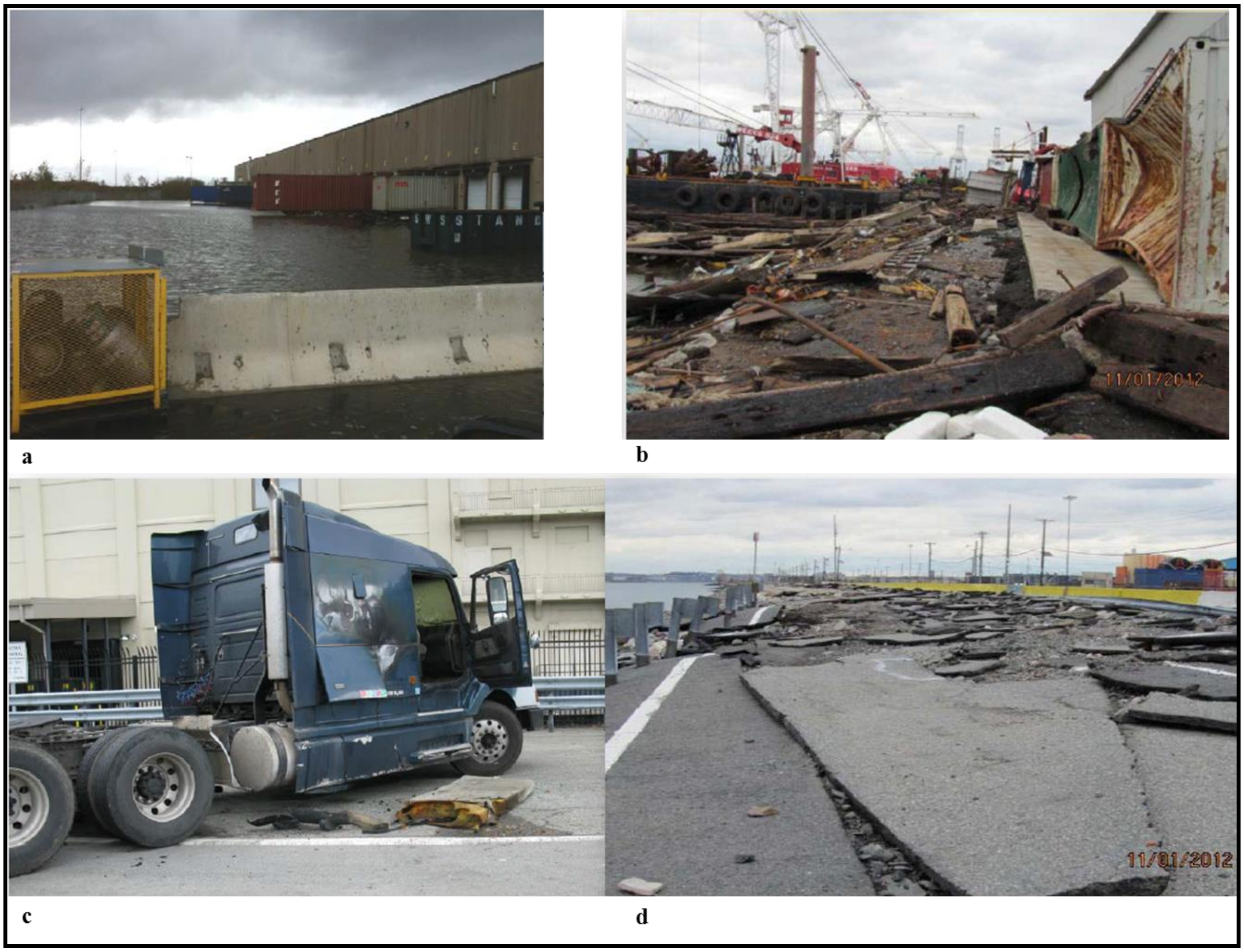

Figure 2.3: Infrastructure damage at various sites: Port of New York and New Jersey
Source(a-d): Southworth et al. (2014) (with permission)

Figure 2.3(a) represents flooding at a loading facility while 2.3(b) highlights the debris and damage at the Greenville terminal; Figures 2.3(c) and (d) show damage to both drayage vehicles and damage to the access road leading to port facilities.

The storm caused cargo to either be diverted to other ports on the East Coast or left cargo stranded at the Port of New York and New Jersey when the facility suspended operations. Approximately fifty-seven vessels diverted to other ports along the Eastern Seaboard and Canada, amounting to a diversion of nine thousand automobiles and twenty-five thousand containers from the Port of New York and New Jersey (Lombardi 2014; Strauss-Wieder 2014, 2012). However, some argue that the container diversion was closer to fifteen thousand rather than the twenty-five thousand (Flynn, 2015). For cargo already in the Port, empty containers were blown over, with damage to vehicle imports stranded in the holding yards, as illustrated in Figure 2.4.

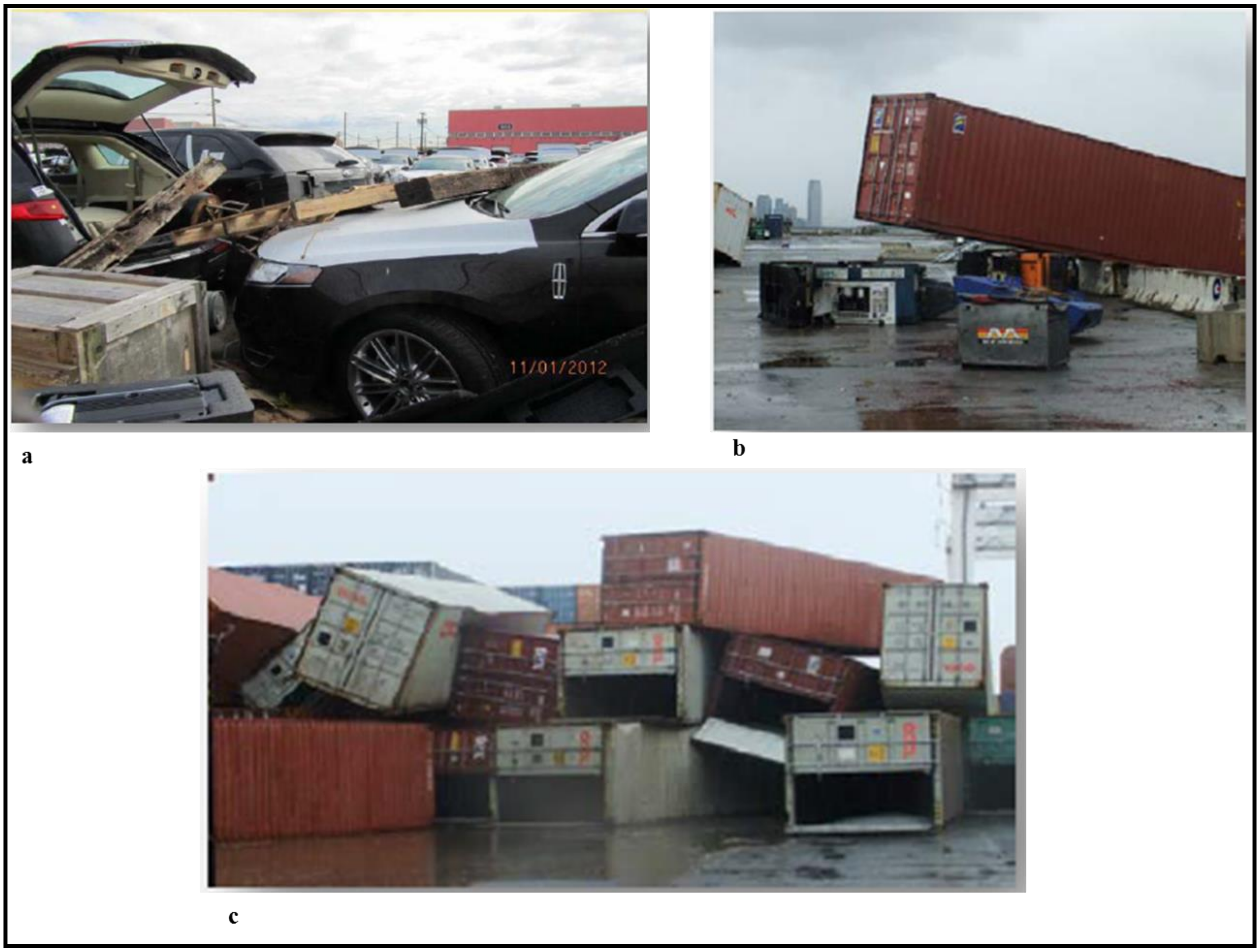

Figure 2.4: Cargo damage resulting from Hurricane Sandy
Source(a-c): Southworth et al. (2014) (with permission)

Despite the damage at the various facilities, the Port was able to recover quickly and clean-up any damage caused by the storm. By Friday November 2, 2012, the United States Coast Guard (USCG) re-opened the Port to deep draft commercial vessels, with power restored to other facilities the following day (Strauss-Wieder, 2014). By the following Monday, November 5, 2012, all container terminals reopened and were servicing vessels. Although the Port resumed operations relatively quickly (approximately one week from suspension of operations to vessels calling at the Port), challenges remained for re-establishing connectivity with railway and highway infrastructure (Sturgis, Smythe, and Tucci, 2014; Smythe, 2013).

2.3.3 Impacts on the Port of Virginia and Norfolk International Terminal

Similar to the Port of New York and New Jersey, the Port of Virginia is a multi-facility port centered on the harbor of Hampton Roads. The facilities under the jurisdiction of the Virginia Port Authority include the Norfolk International Terminal (NIT), the Newport News

Marine Terminal (NNMT), and the Portsmouth Marine Terminal (PMT), amongst other terminals. As illustrated in Figure 2.5, most of the facilities are located around the Hampton Roads-Norfolk area, although the Virginia Port Authority does operate the Virginia Inland Port in Front Royal, Virginia.

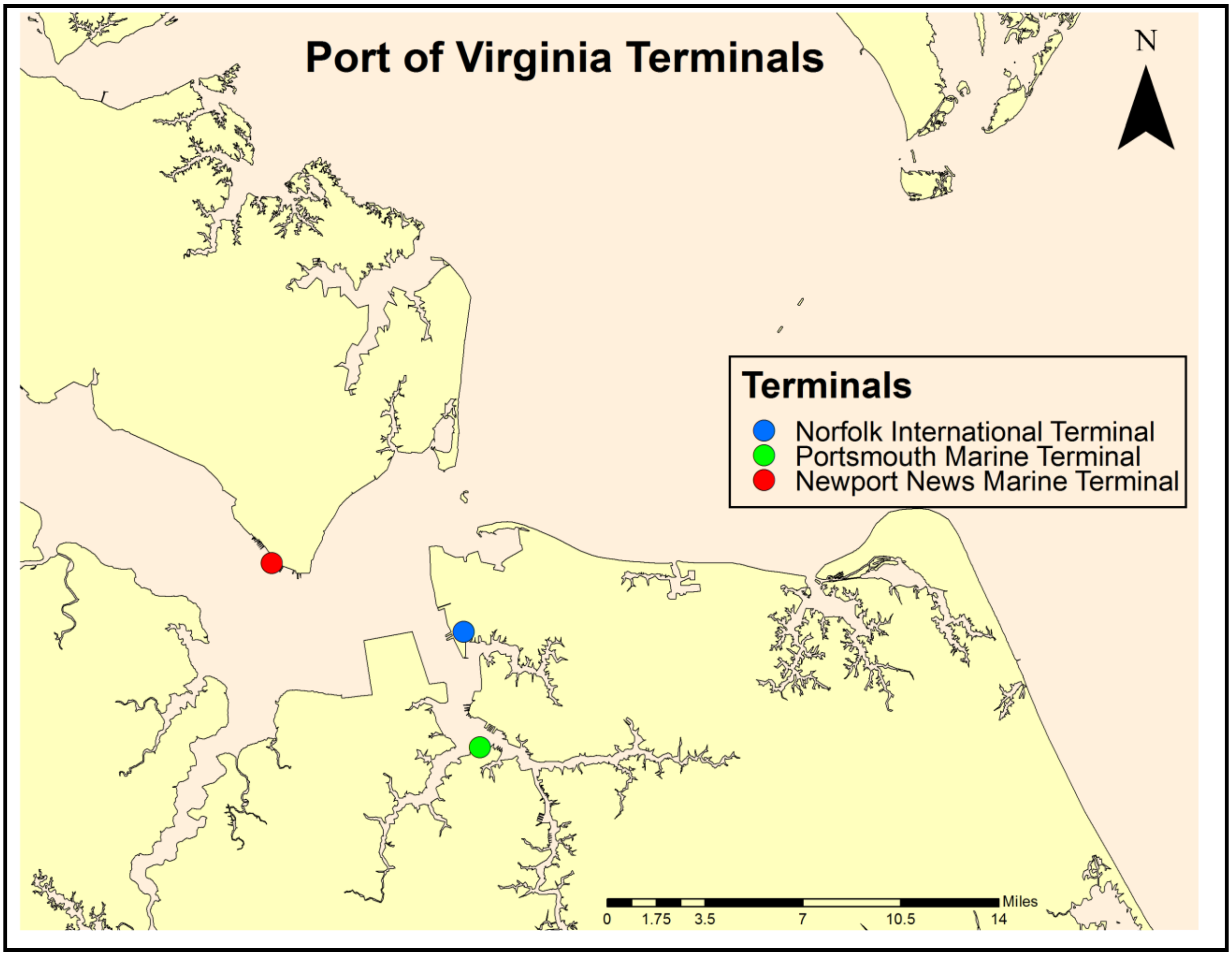

Figure 2.5: Port of Virginia Terminals
Source: M. Fialkoff (2017)

On October 28, 2012, when PANYNJ suspended operations at the Port of New York and New Jersey, CBP began to notify inbound vessels that because of New York suspending operations, vessel traffic was to divert to other ports. CBP notified incoming vessels that available diversion ports included Port of Boston, Port of Philadelphia, Port of Virginia (Norfolk), Port of Charleston, and Port of Savannah (CBP, CSMS bulletin, # 12-0004888, 2012). Diverting vessels could decide to slow down, speed up, or choose the next port in their rotation to avoid the need for diversion (Southworth *et al.* 2014). Container vessels either diverted to the Port of Virginia (NIT), or traveled north to the Port of Halifax (Chope and Florin, 2016).

Approximately 6,500 containers diverted to Norfolk while another 8,500 containers traveled to Halifax (Chope and Florin, 2016; McInnes, 2016). Figure 2.6 presents the freight flow diversion for containers due to the hurricane.

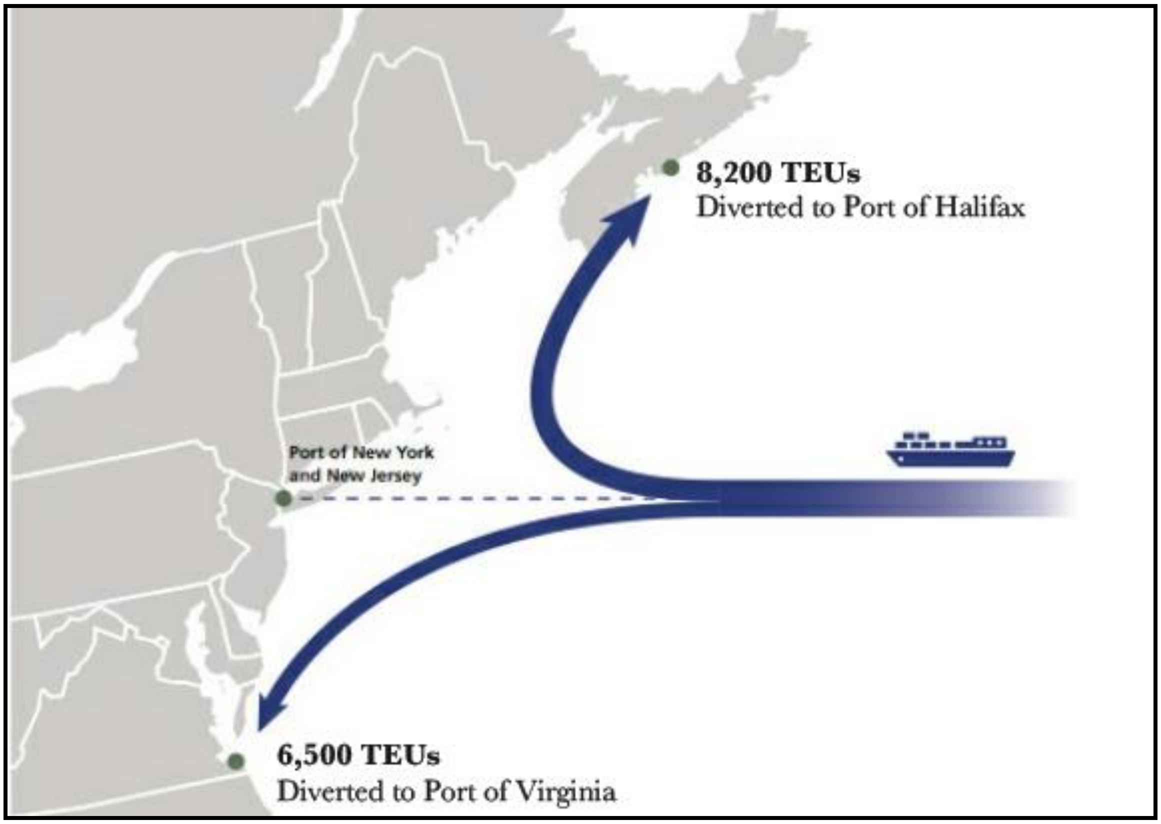

Figure 2.6: Container diversion flow
Source: Flynn (2015) (with permission)

In November 2012, the Port of Virginia and its facilities moved 198,720 containers, a 21.2% increase from November 2011 (McCabe, 2012). While acknowledged that this increase was across the board at all facilities, articles reporting on the impact of the storm on freight traffic through Norfolk acknowledged the fact that an estimated 6,500 containers passed through NIT because of vessel diversions resulting from the closure of the Port of New York and New Jersey. These additional 6,500 containers accounted for 7% of the total number of containers moved through NIT in November 2012 (McCabe, 2012).

In terms of getting the freight out of NIT, a multimodal effort was put forward to clear the additional cargo from port grounds. Of the 6,500 diverted containers, approximately 2,100 containers were barged out of NIT, while the remaining containers left NIT via road and rail haulage (Villa, 2016). November 2012 saw a record number of automobiles transported out of NIT, 478 cars for the month of November, a 40.3% increase from the previous November

(McCabe, 2012). According to Norfolk Southern, sufficient rail cars existed at NIT to handle increased rail traffic because NIT is considered an "export heavy" facility and empty railcars were available on or near the facility (Luebbers, 2016). Given the path of the storm and how it landed north of Norfolk, the storm did not disrupt the natural flow of freight passing through NIT. Since cargo diverted to a naturally export-directed facility such as NIT, locally available rail cars assisted getting the additional containers out of the facility (Luebbers, 2016).

When comparing the 2011 and 2012 container thru-put at NIT, there is a sudden spike in container traffic when the Port of New York and New Jersey suspended operations, as represented in Figure 2.7. Comparing similar time-periods and container thru-put for other container terminals managed by the Port of Virginia, namely the Newport News Marine Terminal and the Virginia International Gateway, there was no change in container volumes.

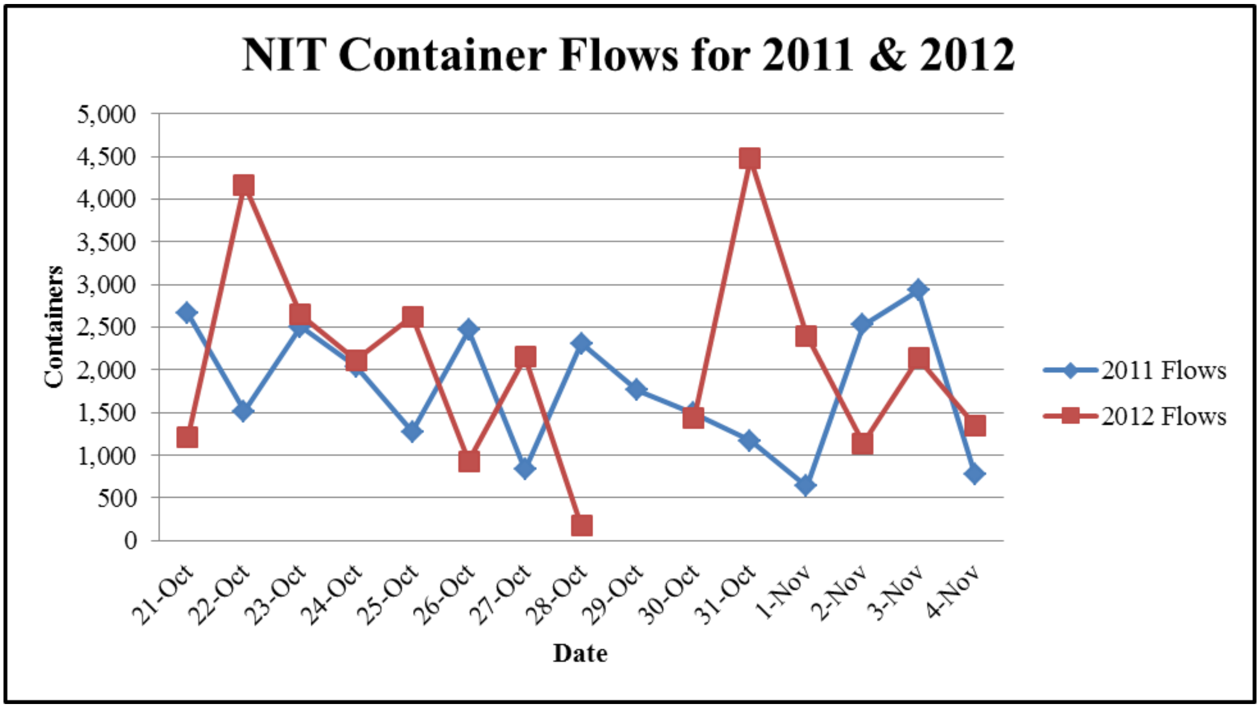

Figure 2.7: Container thru-put for Norfolk International Terminal (NIT)
Source: Chope and Florin (2016)

2.3.4 Impacts on the Freight Transportation Network

When examining the broader network effects of Hurricane Sandy and the suspension of operations at the Port of New York and New Jersey, there are examples of what Southworth *et al.* (2014) described as *modal flexing*. Modal flexing is the ability for other modes to pick up the slack if a mode suffers damage or disruption in operation. The events surrounding freight movement after Hurricane Sandy highlight some examples of modal flexing. First, Columbia

Coastal marshaled additional barges to move diverted containers out of NIT back to the New York metropolitan area. The approximate transit time from Norfolk to New York was thirty-six hours, with an additional ten hours factored in for loading and discharge of the barges (Villa, 2016). A primary reason given for Columbia Coastal's assistance in the evacuation of cargo from Norfolk was the desire by their customers to get their freight faster than waiting for clearance and transit via rail or road haulage (Villa, 2016). In Villa's estimation, the complete evacuation of 2,100 containers from NIT using two barges took approximately twelve days. Aside from Norfolk, Columbia Coastal's operations between Dundalk terminals at the Port of Baltimore could handle any additional containers diverted to Baltimore (Southworth *et al.*2014).

Similar to the efforts by Columbia Coastal, railroad and road haulage shouldered additional traffic because of increased freight loads throughout the network. Containers diverted to Philadelphia were close enough to New York (<100 miles), available trucks brought diverted freight back to the tri-state area. Because of the natural traffic pattern of freight leaving NIT, Norfolk Southern had extra cars available to support increased traffic out of NIT (Luebbers, 2016). For their part, CSX created special rail shuttles between Norfolk and the Kearney yard in New Jersey to support freight traffic moving north (Southworth *et al.* 2014). Once these trains were cleared for transit out of NIT, they traveled north. Since Norfolk Southern operations were not severely affected by the storm, no new traffic routes were necessary and Norfolk Southern could assist CSX with providing additional trackage rights on NS lines (Southworth *et al.* 2014).

2.4 Reflections and Recommendations from Previous Research

In the aftermath of Hurricane Sandy, there was an opportunity to pause and reflect. The cost of damage and recovery from the storm was approximately sixty-eight billion dollars (U.S.) (Flynn, 2015). Approximately 20% of commercial trucking in the Northeast stalled, resulting in an economic loss of one hundred-forty million dollars (U.S.) per day (Henry *et al*. 2013). While reports calculated the damage, the disruption, the displacement, and the number of injured and dead, the reports looked forward, asking questions of how do we as society build our infrastructure better, coordinate our resources, and plan for these threats in the future.

2.4.1 Impacts on the Port of New York and New Jersey

Following Hurricane Sandy, a variety of studies analyzed the impact of Hurricane Sandy on the physical assets of the Port, but also, how did Port stakeholders interact, coordinate, and respond to the events that unfolded during and in the immediate aftermath of the storm. In his final report on how Hurricane Sandy affected the Port of New York and New Jersey, Wakeman (2013) came to two conclusions. First, regardless of how well planners and engineers design and build infrastructure, it can fail. Second, that "the human spirit is the true source of resilience" and is harder to quantify (Wakeman, 2013 p.40). This conclusion stemmed from findings relating to the existing planning culture with Port stakeholders and the creation of the Maritime Transportation System Recovery Unit (MTSRU). The planning culture, coordination of agencies, and centralization of operations within the MTRSU and the ability for the Port Authority to coordinate with multiple stakeholders enabled a speedy recovery (Wakeman, 2013).

Around the same time that Wakeman conducted his study, a similar study was being conducted that focused on the Port stakeholders and the MTSRU's activities before, during, and after the storm. The research conducted by Smythe (2013) focused on stakeholder interviews with individuals from:

- USCG,
- New York Fire Department (NYFD),
- New York City Department of Transportation (NYCDOT),
- PANYNJ,
- National Oceanic and Atmospheric Administration (NOAA),
- U.S. Army Corp. of Engineers (USACE),
- Sandy Hook Pilots Association,
- Maritime Administration (MARAD), and
- New Jersey Office of Homeland Security and Preparedness (NJOHSP).

The research chronicled the preparation of the Port, its stakeholders, and the formation of the MTSRU. The MTSRU is a subcommittee of the Area Maritime Security Committee, led by the USCG. The purpose of the MTSRU is to address issues related to safety and security within the Maritime Transportation System (MTS). The MTSRU was formed in compliance with provisions of the Maritime Transportation Security Act (MTSA). In the case of Hurricane Sandy, the primary responsibility of the MTSRU was to facilitate coordination and assist in reopening the Port and its maritime activities. The MTSRU is a multi-stakeholder committee comprised of stakeholders representing local, state, and federal government agencies, the Port Authority, and representatives from the terminals, refineries, and organizations that support port operations (linesmen, stevedores, tugboat operators). As part of the planning process, the Coast

Guard, through the work of the Captain of the Port and other stakeholders developed numerous plans in preparation for and responding to severe weather events. In the context of the Port of New York and New Jersey, the Coast Guard had two plans available, the *Hurricane and Severe Weather Plan* for Sector New York and its companion, *Captain of the Port New York Hurricane and Severe Weather Plan for the Port of NY and NJ.* These plans provided step-by-step instructions for handling severe weather events, coordinating maritime stakeholders, and procedures for shutting down the Port safely.

Towards the end of the report, a summary of lessons learned and successes and challenges going forward highlighted the importance of the MTSRU and the work it still had to accomplish going forward. The success and challenges are presented in Table 3.2.

Table 2.2: Findings from Port Stakeholder Interviews

Successes	Challenges
Coordination of Stakeholders within the Port	Storm Surge
Relationship and Trust	Electrical Power
Prior Experience	Fuel
Beyond Planning: Expertise and Improvisation	Waterfront Buildings and Structures
Value of Maritime Assets	Waterfront Electrical Infrastructures
	Coordination with External Partners/Sectors
	Data and Information
	"Messaging" the Port
	Personnel Management

Source: Smythe (2013)

In comparing the successes and challenges, many of the challenges faced by the port involved management and protection of infrastructure vulnerable to damage, especially electrical power at the waterfront, and building flooding. Many successes were attributed to careful planning by the MTSRU and the coordination of maritime partners in preparing and executing the plans for severe weather events. Regardless of the best plans though, many of challenges focused on infrastructure failure, reiterating Wakeman's first conclusion from his own research (Smythe, 2013; Wakeman, 2013). With the Port losing power and fuel shortages, recovery efforts slowed since the port relied on other infrastructure systems to recover before they could restart.

A subsequent study analyzing the MTSRU and its coordination in the aftermath of the hurricane came to similar conclusions from the work of Smythe (2013) (Sturgis, Smythe, and Tucci, 2014). In contrast to the previous study conducted by Smythe in 2013, this report focused on challenges presented by a lack of integration of rail and road connectivity in port recovery planning (Sturgis, Smythe, and Tucci, 2014). Although the Port was moving towards restoring operations through the efforts of the MTSRU, the intermodal connectivity with rail and road operators was limited. The primary issue presented was a lack of communication between Port stakeholders and other surface transportation stakeholders. During the shut-down procedure for the Port, many of the drayage vehicles and rail cars remained in low-lying areas within the port. Instead, these vehicles should have been moved to higher ground to avoid damage. Because the vehicles stayed in the port, approximately 4,500 chasses and rail cars were either lost or damaged (Sturgis, Smythe, and Tucci, 2014). Those vehicles damaged or stalled became debris and impeded recovery for the rail and road infrastructure operators. While the MTSRU coordinated with Port stakeholders, an all-modes approach going forward is necessary if multimodal transportations operations are to recover.

2.4.2 Freight Transportation Network

Whereas the previous Section described the impact at the Port and lessons learned from the MTSRU, the impacts resulting from Hurricane Sandy affected the multimodal freight transportation network. The lack of intermodal communication led to asymmetric recovery between the Port and other landside modes and a sense of disjointed multimodalism. What lessons did the transportation scholars learn from Hurricane Sandy as it related to the freight transportation network and what can be done going forward to facilitate recovery?

Starting in 2012, a series of reports sponsored by TRB focused on studying the economic and network effects of disruptions in general. The second report in the series focused on Hurricane Sandy and its effects on the freight transportation network. In, *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System* (NCHRP Report 732), different methodologies were assessed relating to their viability in studying disruption on freight transportation networks (Georgia Tech Research Corporation *et al.* 2012). The report differentiated between economic and network effects, determining that the economic impact and the network impact required separate treatment. Rather, different models focused on economic complexities versus network complexities (Georgia Tech Research Corporation *et al.* 2012). The report concluded that the greater the disruption, the greater network pressures are for the maritime and other surface modes. Thus, the greater the number of ports and intermodal terminals affected by a disruption, the greater potential there is for more significant impacts.

A follow-up report, *Making US Ports Resilient as Part of Extended Intermodal Supply Chains* (NCFRP Report 30) focused on port resilience and its impact on supply chains (Southworth *et al.* 2014). In this report, the authors focused on understanding the physical, geographic, and regulatory considerations involved in responding to freight disruptions. Although similar in research methodology to Smythe's (2013) report, the conclusions drawn by NCFRP-30 focused on the impacts of disruption on the overall freight network, in contrast to just a port (Southworth *et al.* 2014). For example, the conceptual development of *modal flexing* in NCFRP-30 indicated a focus on how a disruption at a facility, such as a port, could have cascading impacts across various modes (Southworth *et al.* 2014).

In contrast to *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System*, *Making US Ports Resilient as Part of Extended Intermodal Supply Chains* examined the regulatory implications associated with disruptions. The report raised CBP's role in clearing diverted freight, truckers not having local clearances, and the issue of the Jones Act as barriers to modal flexing (Southworth *et al.* 2014). The first two issues presented operational challenges in comparison to the Jones Act, which is legal, but also a policy issue that could not be resolved as fast as the first two. If the Jones Act was relaxed, vessels could pick up diverted freight based on the vessel's port rotation, releasing pressure on land based modes, and relieving any additional congestion that may occur (Southworth *et al.* 2014).

The recommendations from NCFRP-30 ranged from operational strategies to long-term policy changes. For the Jones Act, a more liberal waiver policy allowing general cargo vessels to apply for waivers would alleviate pressure and provide further modal flexing for the freight network (Southworth *et al.* 2014). The final recommendation in the report suggested further identification and assessment of the challenges associated with freight diversion, focusing on other regulatory challenges (Southworth *et al.* 2014).

In addition to the conclusions reached by Southworth *et al.* (2014), further work on recovery efforts after Hurricane Sandy singled out the Jones Act waiver process as a barrier to recovery. Instead of the blanket analysis conducted previously, the critique of the Jones Act focused on the waiver process. Specifically, the waiver process has been criticized for being ad hoc in its decisions and there is no standard process for waiver decisions (Flynn, 2015). Flynn's work goes farther than the recommendations in Southworth *et al.* (2014) in its recommendation to apply big data, Geographic Information Systems, and High Performance Computing to disaster management (Flynn, 2015).

2.5 The Merchant Marine Act of 1920 – The Jones Act

The Merchant Marine Act of 1920, more commonly known as the Jones Act, has been described as a restriction on short sea shipping, a statute allowing U.S. vessels to engage in coastwise trade, and an impediment to freight transportation recovery. However, what exactly is the Jones Act and why do we have this statute in the first place? Chapter provides greater detail on these issues and the legal and regulatory issues associated with the Jones Act and its waiver process, but it is helpful to provide a brief introduction to the relevant provisions of the Statute and provide some context to the necessity of the Jones Act.

Although the Jones Act was enacted 1920, coastwise trade and the law of cabotage have been with our country since its founding. Seeing a need for a strong domestic merchant marine fleet, the first Congress passed a tonnage tax favoring U.S. vessels over those of foreign construction in 1790 (Seifert, 1991). In 1792, a second law was passed with new requirements on construction and citizenship for those vessels operating in U.S. waters (Seifert, 1991). The issue remained somewhat dormant through the early portion of the nineteenth century; however, at the end of the Civil War, the issue of U.S. vessels reemerged because of overwhelming losses of U.S. shipping to foreign vessels and the inability of these vessels to meet the requirements of the 1792 Act. Almost three-quarters of a million tons of U.S. commerce were lost to foreign vessels. This restriction further led to a one-third reduction in the U.S. merchant marine fleet.

With the entry of the United States into World War I, merchant marine vessels were in short supply as they were needed for the war effort. Because of dwindling U.S. built vessels, the original policy rationale for the Jones Act was described in Section 50101 of United States Code, which read in part:

> [I]t is necessary for the national defense and for the proper growth of its foreign and domestic commerce that the United States shall have a merchant marine of the best equipped and most suitable types of vessels sufficient to carry the greater portion of its commerce and serve as a naval or military auxiliary in time of war or national emergency, ultimately to be owned and operated privately by citizens of the United States; and it is hereby declared to be the policy of the United States to do whatever may be necessary to develop and encourage the maintenance of such a merchant marine… (Cook, 1991 p. 6).

While Section 50101 states the policy rationale for U.S. vessels engaging in coastwise trade, the operative legal requirements can be found in 46 U.S.C § 55102 which:

> …provides that the transportation of merchandise between U.S. points is reserved for U.S.-built, owned, and documented vessels. Pursuant to the above-mentioned section, 'a vessel may not provide any part of the transportation of merchandise by water, or by land and water, between points in the United States to which the coastwise law apply, either directly or via a foreign port, unless the vessel- (1) is wholly owned by citizens of the United States for purposes of engaging in the coastwise trade; and (2) has been issued a certificate of documentation with a coastwise endorsement under chapter 121 of Title 46 or is exempt from documentation would otherwise be eligible for such a certificate and endorsement. (U.S. Department of Homeland Security, CBP, 2009).

Although the requirements in place restrict foreign vessels from engaging in coastwise trade, the provisions of the Jones Act do provide a waiver process to allow these vessels to engage in coastwise trade under narrow circumstances. According to 46 U.S.C. § 501, the Jones Act can only be waived in the interest of national defense. Under these circumstances, a waiver request is made to the Secretary of Defense. For waiver requests not related to national defense, waiver requests are submitted to the Secretary of Homeland Security who reviews the application, in consultation from the Administrator of the Maritime Administration (MARAD). In this instance, the MARAD Administrator is consulted to determine the availability of qualified U.S. vessels.

Since its passage in 1920, the debate over the effectiveness of the Jones Act has been well documented. It has been argued that it is time for the Jones Act to be reformed, as it was an antiquated law that posted economic barriers to maritime commerce and posed issues for developing short sea shipping as an alternative mode of freight transportation (Yost 2013). Proponents of the Jones Act argue that it is an essential tool in national security and any thought of reformation or removal would prove dangerous to domestic maritime security (Gouré 2016a; 2016b). In the context of critical infrastructure resilience and disaster response, the Jones Act has received mixed treatment, with the Act being completely suspended in the aftermath of Hurricane Katrina and then a more narrow suspension in the case of Hurricane Sandy. This raises the question; to what extent does the Jones Act affect the movement of freight through the freight transportation network? With recent calls by the Transportation Research Board and the National Cooperative Freight Research Program to study the effect of law and institutional factors on freight diversion, the role of the Jones Act continues to be a law needing further study and analysis.

2.6 Summary

This chapter introduced Hurricane Sandy and its impact on transportation infrastructure. Over the course of the chapter, the complexity involved with coordinating stakeholders, operating within regulatory and policy frameworks, and recovering from a disaster such as Hurricane Sandy presents a conceptual challenge. In the case of freight transportation, the Jones Act has been criticized as a barrier to freight recovery. Given the Jones Act, the waiver process implementation, and the perceived impact of the Statute on freight transportation networks, what is the proper conceptual framework for analyzing the effect of a law on pieces of infrastructure? More broadly, how do the legal system and the regulatory system interact with a physical infrastructure system like transportation?

Given the need to consider how law and policy might affect freight, the next chapter develops a conceptual framework that recognizes the complexity of multiple systems interacting with emergent behaviors based off the interactions from the interacting systems. Chapter 3 will introduce the System of Systems framework that will structure the research methodology.

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Chapter 3: Literature Review and the System of Systems Framework

3.1 Introduction

Chapter 2 introduced the case of Hurricane Sandy and its impact on the freight transportation network. Specifically, the chapter introduced the Jones Act and highlighted the frustration by some with the inability to obtain a waiver. The recommendations to relax the Jones Act helped formulate the research question, what effect does relaxing the Jones Act have on freight transportation in the aftermath of disruptions.

This chapter provides a literature review for investigating the relationship between law and policy and the infrastructure systems they govern. Section 3.2 will summarize the Critical Infrastructure Protection literature, focusing on the institutional and legal challenges in critical infrastructure policy and governance. Literature from Institutional Theory and on law and resilience explains that the inability of law and institutions to adapt to uncertainty can affect infrastructure. Section 3.2 will also briefly introduce the methodological literature for network diversion analysis, which Chapter 4 further discusses. Building off the resilience discussion started in Section 3.2, Section 3.3 will briefly provide an overview on the evolving resilience literature and how freight transportation research incorporates the resilience discourse into its research.

The second part of Chapter 3 also develops a framework to study the interaction of multiple systems. A dominant view in transportation research has been to view transportation as a system. Transportation systems bring together multiple components and stakeholders, but the traditional Systems Thinking does not adequately address issues of resilience and the interaction of multiple systems. First, traditional Systems Thinking does not address relationships between complex independent systems. Second, when multiple systems interact, new behaviors develop and Systems Thinking does not account for such emergent behaviors.

This chapter will propose an alternative framework. The recent development of the System of Systems framework addresses the shortcomings in the traditional view of Systems Thinking. First, a System of Systems framework recognizes the autonomy and managerial independence of systems; meaning that systems may function on their own, without interaction with other systems. Second, a System of Systems framework accounts for emergent behavior by recognizing that interacting systems will result in unforeseen results given the interaction. To illustrate the System of Systems framework for this research, Figure 3.1 highlights the multiple interacting systems involved with relaxing the Jones Act and its subsequent impact on the freight transportation network. Each "plate" within Figure 3.1 represents a different system and changes in one system impacts the other. This conceptual framework recognizes the law as a separate and independent system and changes in the law affect the administration of the law and its subsequent implementation for transportation operations. Sections 3.4.2 and Section 3.5 will further explain Figure 3.1.

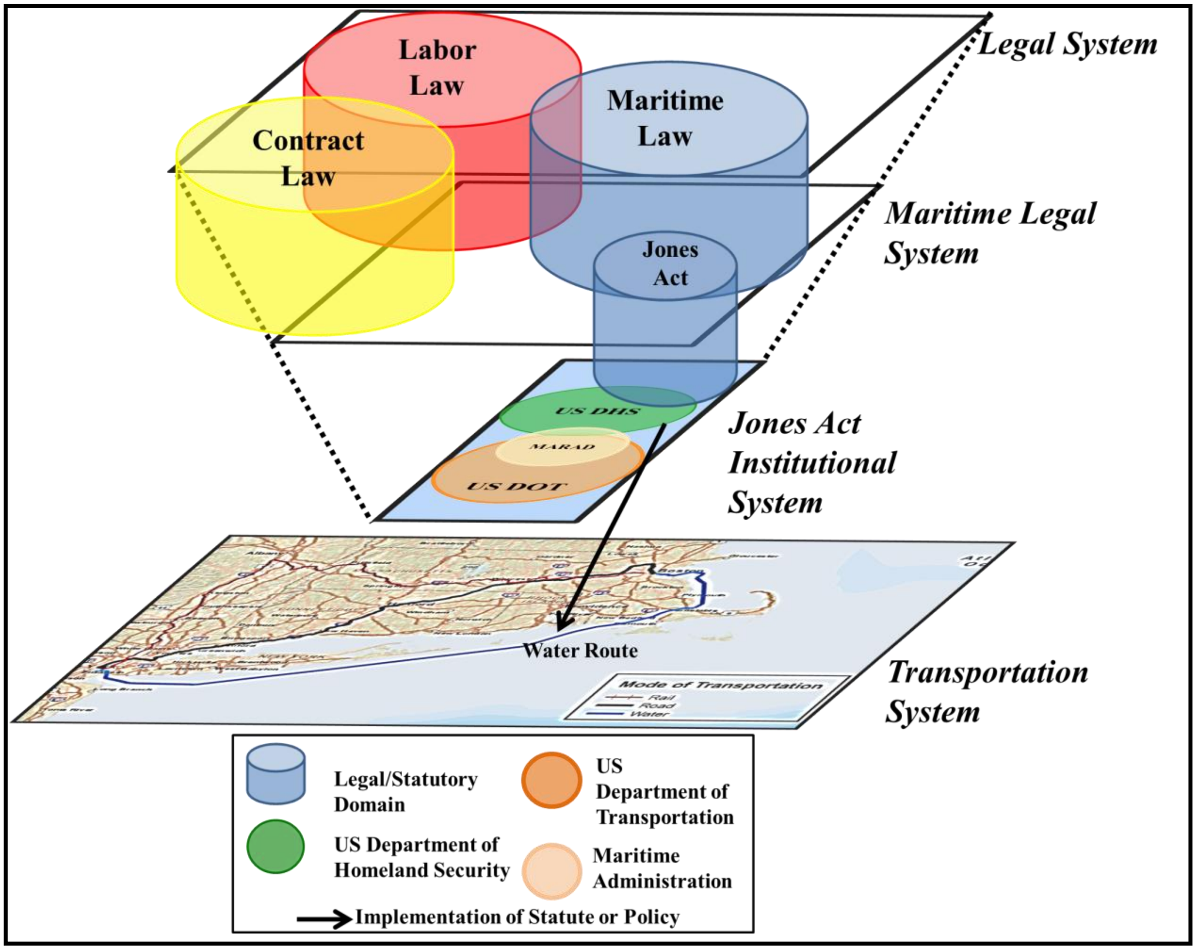

Figure 3.1: System of Systems framework for relaxing the Jones Act
Credit: M. Fialkoff (2017)

3.2 Critical Infrastructure Protection Literature

The concept of Critical Infrastructure has its origins in the Cold War. It originally focused on communication systems but expanded to include multiple infrastructure systems that support society today. *Critical Infrastructure* is a term that refers to "man-made networks and systems that provide needed goods and services to the public" (Pesch-Cronin and Marion, 2017, p.4). There are sixteen sectors that are described as Critical Infrastructure by the federal government, listed in Table 3.1.

Table 3.1: Critical Infrastructure and Key Resource Sectors

Chemical	Financial Services
Commercial Facilities	Food and Agriculture
Communication	Government Facilities
Critical Manufacturing	Healthcare and Public Health
Dams	Information Technology
Defense Industrial Bases	Nuclear Reactors/Waste/Materials
Emergency Services	Transportation Systems
Energy	Waste/Wastewater Systems

Source: Newsome and Jarmon (2015)

Although discrete infrastructure systems, they are interconnected, traverse geographic boundaries, domains, multiple disciplines, and range in ownership from purely public, to quasi-public, public-private, or completely private. These infrastructures "[are] the connective tissue that knits people, places, social institutions, and the natural environment into coherent urban relations" (Graham and Marvin, 2001, p. 43). This connectivity also is between political institutions and the infrastructures they govern (Kröger, 2008). Recognizing infrastructure sectors are interdependent; four categories describe the different types of interdependency and can take four forms:

- Physical: output of one infrastructure is used by another,
- Cyber: infrastructure depends on information transmitted through the information and communication infrastructure,
- Geographic: two or more infrastructures are co-located in the same area and can be affected by a local event, and
- Logical: the state of one infrastructure is dependent on the state of another infrastructure that is not physical, cyber, or geographic (*e.g.*, economic markets, law, or policy) (Rinaldi, Peerenboom, and Kelly, 2001).

In response to growing threats to critical infrastructure systems, recent policy directives instruct federal agencies to inventory, coordinate, and analyze critical infrastructure vulnerabilities. These Sector Specific Agencies (SSAs) developed strategic plans for identifying critical infrastructure assets and provide suggestions for protecting them against threats (Fialkoff *et al.* 2017). For transportation, multiple agencies participate in developing the Sector Specific Plan (SSP). The agencies involved include the U.S. Department of Transportation (DOT), the Transportation Security Administration (TSA), and the U.S. Coast Guard (under the jurisdiction of the DHS). In compliance with Presidential Policy Directive 21 (PPD-21), these agencies developed and submitted a Transportation Sector Specific Plan as part of the National Infrastructure Protection Plan in 2010, subsequently amended in 2015.

Although there is growing interdependency between infrastructures and coordination between federal agencies, there is evidence of fragmentation. The Transportation Sector Specific Plan is an example of such fragmentation. The Transportation Sector Specific Plan consists of seven sub-sectors, representing the major modes of transportation, as illustrated in Table 3.2.

Table 3.2: Transportation Sector Specific Plan Sub-Sectors

Aviation
Highway Infrastructure and Motor Carriers
Maritime Transportation Systems
Mass Transit and Passenger Rail
Pipelines
Freight Rail
Postal and Shipping

Source: U.S. DHS (2010)

The Plan does not discuss freight transportation generally; rather, the freight rail sub-sector is the only sector that goes into detail on freight transportation. There is no sub-sector on multimodal freight transportation or intermodal connectivity. Although the Plan does not explain the absence of such a sector, one potential explanation could be the institutional arrangements within the DOT; specifically, the modal orientation of the DOT and the balkanization within the modal sub-agencies.

Another example of fragmentation within the Transportation Sector Specific Plan is the different definitions for resilience. Overall, the Plan envisions "a secure and resilient transportation system, enabling legitimate travelers and goods to move without significant disruption of commerce, undue fear or harm, or loss of civil liberties" (U.S. DHS, 2010). Although the National Infrastructure Advisory Council (NIAC) developed a working definition of resilience as "the ability to reduce the magnitude and or direction of disruptive events," the Sector Specific Plan defined resilience as the "transportation sector's ability to resist, absorb, recover from, or successfully adapt to adversity or change in condition" (U.S. DHS, 2010). Even between the sub-sectors, the Plan described different modes of transportation as having different definitions of resilience with no common definition of resilience for intermodal freight transportation.

3.2.1 Institutional Theory and its Role in Critical Infrastructure Governance

The fragmentation described in the previous section is not a product of the difference in infrastructure, but the result of institutional fragmentation. Over decades of deregulation, privatization, and liberalization, institutional oversight devolved to private sector actors, leaving delivery and operations to private companies (de Bruijne and van Eeten, 2007). Because of this restructuring of institutional oversight and control, institutional coordination of critical infrastructure systems declined, resulting in negative impacts when faced with "demanding conditions" (de Bruijne and van Eeten, 2007). Facing these "demanding conditions" with limited government oversight, infrastructure managers have looked for alternative pathways for flexibility during these periods. Such pathways include working with other private infrastructure managers instead of the government because the government is unreliable in uncertain situations (de Bruijne and van Eeten, 2007). This mistrust leaves government institutions in the precarious position of relying on the private sector to ensure critical infrastructure is secure and resilient.

Although focused on critical infrastructure and the impact of institutional fragmentation in that context, this issue is part of a larger literature based in Institutional Theory. For example, the fragmentation of regulatory agencies is not by circumstance, but by design of the legislature (Freeman and Rossi, 2011). In the case of the American Administrative State, Freeman and Rossi identified factors that lend themselves to institutional fragmentation. First, the bicameral structure of Congress and the committee system forces agencies to report to different committees in the House of Representatives and the Senate (Freeman and Rossi, 2011). Committees in both the House and the Senate have oversight prerogative over agencies, with different committees delegating different priorities and powers to the various agencies. At the agency level, a series of inter-agency "fire alarms" exist, where agencies provide checks and balances over one another based on the powers delegated to the agency from the enabling statute (Freeman and Rossi, 2011). In this case, the agencies work against one another as a means of maintaining accountability instead of coordinating.

There is a long history of institutional fragmentation and challenges associated with intermodal freight transportation planning. In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) sought to strengthen intermodal freight planning efforts, though structural problems in the U.S. DOT prevented integrated freight planning. In 2003, the Government Accountability Office (GAO) began studying the institutional challenges associated with DOT efforts in freight planning. The results of the study indicated that institutional ossification and the organization within the DOT presented fundamental problems with the coordination of freight planning (GAO-04-165, 2004). The GAO determined that in addition to institutional fragmentation based on mode, funding from ISTEA and the subsequent Transportation Equity Act for the 21st Century (TEA-21) established federal funding and programs for surface transportation projects based on mode. Coordination across modal agencies and stakeholders is limited based on the funding model established in ISTEA and TEA-21. Since different sub-agencies within the DOT have different missions, their level of freight planning capability is either limited or non-existent. Reiterating the findings from their 2004 report, the GAO concluded that the Intermodal Transportation Council, the organization established within DOT to support intermodal planning efforts, suffered from insufficient authority to coordinate freight activities across the modal agencies (GAO 07-718, 2007).

In an attempt to reorganize the DOT to eliminate the modal balkanization, the GAO proposed a reorganization plan in 1995. The plan called for the elimination of the modal agencies and the creation of a surface transportation sub-agency and an aviation sub-agency (Hall and Sussman, 2006). This effort to reorganize the DOT ultimately failed. From the perspective of the sub-agencies involved, any reorganization would have affected their funding. More importantly, any reorganization would have threatened their existence, which is contrary to their primary purpose, gaining legitimacy and protecting their constituencies to preserve such legitimacy (Rowan and Meyer, 1977). From the perspective of Congress, a reorganization of the DOT affects committee oversight and review. Table 3.3 presents the congressional committees with oversight over transportation related policies. In the event of any reorganization, the congressional committees affected would review such reorganization within their committee. This piecemeal approach would slow down any interagency reorganization or any interagency attempts at coordinating a policy for integrated freight planning (Hall, 2006).

Table 3.3: Congressional Committees with Transportation Policy Oversight

House Committees and Subcommittees	Senate Committees and Subcommittees
Appropriations Committee • Subcommittee on Transportation, Treasury, and Housing and Urban Development • Subcommittee on Homeland Security	**Appropriations Committee** • Subcommittee on Transportation, Treasury, the Judiciary, Housing and Urban Development, and Related Agencies • Subcommittee on Homeland Security
Transportation and Infrastructure Committee • Subcommittee on Aviation • Subcommittee on Coast Guard and Maritime Transportation • Subcommittee on Highway, Transit, Pipelines • Subcommittee on Railroads	**Environment and Public Works Committee** • Subcommittee on Transportation and Infrastructure
Budget Committee	**Commerce, Science, and Transportation Committee** • Subcommittee on Aviation • Subcommittee on Surface Transportation and Merchant Marine
Homeland Security Committee	**Banking, Housing, and Urban Affairs Committee** • Subcommittee on Housing and Transportation
Ways and Means Committee	**Budget Committee**
	Finance Committee

Source: Hall (2006)

The concern of agencies protecting their legitimacy is not exclusive to transportation, but an identified challenge within Institutional Theory. Starting with the work of Meyer and Rowan (1977), the primary concern of agencies is protecting their legitimacy. Agencies regulate their constituencies through regulation and request resources from Congress to regulate their constituents. Over time, established regulations, procedures, and funds stabilize the agencies legitimacy and continue the agencies' institutional significance and power (Meyer and Rowan, 1977). As institutions develop more regulations and their power solidifies, their ability to respond to emerging threats diminishes because of existing rules, structures, and inflexibility (Knox *et al.* 2015).

In the Critical Infrastructure Resilience and Security literature, the inflexibility of agencies to respond to crisis presents fundamental challenges to their adaptive capacity and flexibility. In summarizing these concerns, Garschagen (2013) posed the following question; for agencies faced with developing resilience-based strategies, how can new adaptive practices that promote resilient tendencies be incorporated into institutions ossified by regulations and confined by administrative structures that stymie development? If resilient behavior means adapting to the unforeseen, this challenges core tenets of Institutional Theory- *i.e.*, conformity, order, and legitimacy (Garschagen, 2013). In reality, Institutional Theory and policy science accepts the need to adapt to changing situations through the use of "focusing events" and "windows of opportunity," which allow institutions and policymakers the opportunity to adapt to change, at the time when such change presents itself (Birkmann *et al.* 2010).

Recent research in Institutional Theory tries to pivot towards more robust, adaptive governance models to handle uncertainty. A core aspect of adaptive governance is the ability for institutions to learn to manage complexity and harness resilient behaviors (Vandergert *et al.* 2016). In these new governance models, polycentric institutional models illustrate the need for coordination across multiple power centers and create linkage between individual constituencies across different geographic and jurisdictional scales (Vandergert *et al.* 2016). Such connectivity would reflect the connectivity Marvin and Graham (2001) described with infrastructure; though any sudden change in institutional arrangements could create shocks to constituencies and create further uncertainty (Öberg *et al.* 2014).

3.2.2 A "Mal-Adaptive" System: Law & Critical Infrastructure Governance

The literature analyzing the relationship between law and policy and critical infrastructure is limited. Within the area of emergency management and critical infrastructure protection, law and policy provide framing language for agencies in infrastructure security (Newsome and Jarmon, 2015; Rinaldi, Peerenboom, and Kelly, 2001). The work by Rinaldi, Peerenboom, and Kelly (2001) provides the most insight into the relationship between law and policy and critical infrastructure resilience and security. From their perspective, law and policy are environmental factors, similar to political, social, and economic considerations (Rinaldi, Peerenboom, and Kelly, 2001). Borrowing from the work of Sussman (2000), these factors are similar to "external" variables with the traditional systems description of transportation.

There are gaps within the critical infrastructure literature in relation to the role of law and policy in critical infrastructure governance. The first gap is in the framing of law and policy as environmental factors in relation to infrastructure systems. Law and policy are systems in their own right, and should not be reduced to "factors" (Hart, 1961). Focusing specifically on the Law as a system, Hart explained that the existence of a Legal System is predicated on "the 'union' of primary rules of obligation and secondary rules of recognition, change, and adjudication" (Payne, 1976, p. 289). The reductionist view taken by Rinaldi, Peerenboom, and Kelly (2001) does not accurately reflect the complexity of what constitutes a Legal System. The second gap is limited to how law and policy systems affect the infrastructure systems they govern, especially in the aftermath of a disruption. Disaster response does not happen in a legal and/or policy vacuum, rather it is directed by statutes, regulations, and policies that delegate responsibilities to agencies under specific circumstances (Kapucu, 2006).

Although separate from the critical infrastructure literature, the law and resilience literature analyzes how the legal system poses challenges to fostering resilience. Within the modern American Administrative State, the need for a predictive ability and the reliance on Legal Reductionism has led Western Legal Systems to try and anticipate, predict, and control as much as possible (Ruhl, 1996). Decisions such as *Chevron v. Natural Resource Defense Council* become anathemas to law because they resolve ambiguity for the sake of order through decisions of the agency, rather than through congressional action (Ruhl, 1996). This approach to resolving ambiguity for the sake of order restricts flexibility in governance and reduces adaptive decision-making.

Since Ruhl's work, other research focused on the development of methods, processes, and goals to avoid what Arnold and Gunderson describe as the "mal-adaptive" state of the law. The mal-adaptive state of law is one with linear views to the law that rely on monocentric administration of the law and the ultimate goal of predictability (Arnold and Gunderson, 2013). In contrast, an adaptive legal state allows for the administration of law through multiple institutions and enables evolutionary change, with the law providing discretionary decision-making based off context-specific situations (Arnold and Gunderson, 2013). Table 3.4 illustrates the comparisons between the mal-adaptive view and the adaptive view. While advocating for more flexibility within the administration of law in the Administrative State, scholars such as Ruhl (2010) differentiate the difference between a legal system being resilient and the impact of the law on fostering resilience in systems governed by particular laws. This differentiation is important in that it distinguishes (1) the law is a system unto itself, with the ability for it to facilitate behavior leading to resilience and (2) the Legal System can either foster or stymie resilient behaviors in the systems they govern, including infrastructure.

Table 3.4: Mal-adaptive vs. Adaptive Legal Systems

Feature	Mal-adaptive law	Adaptive Law
Goals	Legal regimes aim to advance particular stability of single systems. Current regimes focus primarily on political and economic goals. Alternative (reform) regimes focus primarily on ecological goals.	Legal regimes aim for multiple forms of resilience: the resilience and adaptive capacity of both social and ecological systems, including constituent subsystems, such as institutions and communities.
Structure	Law is monocentric, utilizing fragmented, and unimodal responses to problems.	Law is polycentric, utilizing multimodal and multi-scalar responses to problems that are loosely integrated.
Methods	Law controls society through rules, limits on action and authority, demand for certainty, and legal abstractions that resist change.	Law facilitates social and ecological resilience through moderate/evolutionary adaptation to changing conditions, context-regarding standards, tolerance for uncertainty, and flexible discretionary decision-making.
Processes	Law presumes rational, linear decision-making and implementation processes by a single authority and the centrality of law to the ordering and management of human affairs.	Law recognizes and embraces iterative processes with feedback loops among multiple participants, limits to human and organizational rationality, and the effects of social and ecological forces on the ordering and management of human affairs, and accountability mechanisms for the conservation of capital.

Source: Arnold and Gunderson (2013)

3.2.3 Studying Network Disruption: Diversion Analysis

For the methods proposed in this dissertation, the transportation and critical infrastructure literature provides ample resources for studying the effect of disruption on networked infrastructure. While Chapter 4 will discuss the models and specific approaches, this section introduces network diversion analysis as a methodology to study the impact of disruption on freight transportation networks.

Specifically in freight transportation, the past ten years have seen various studies in understanding the impact of disruption on freight transportation networks. Much of this effort focuses on state-level disruptions as part of efforts by states to develop resilient statewide freight transportation plans. Washington State developed a GIS-based statewide freight transportation network for studying freight flow through Washington (Goodchild *et al.* 2009). The Washington study focused on mapping the statewide assets and analyzing the impact of disruptions to the road network. The conclusions of the research emphasized the need for developing a "resilience culture" for freight planning in Washington. Other state Departments of Transportation followed the Washington approach, with varying degrees of detail. For example, Texas Department of Transportation (TxDOT) conducted an economic analysis for freight disruption within Texas (Statewide Freight Resiliency Plan, 2011). Compared to Washington, Texas focused less on GIS and more on economic losses resulting from a disruption to freight.

Since 2012, the Transportation Research Board TRB commissioned studies to examine the impact of disruption and methods for analyzing disruption for the transportation network. The first report, *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System,* (NCHRP-732) categorized the difference between economic impacts and network impacts because of disruptions. Economic losses focused on the impacts on supply chains and the cost of disruption, for the customer, shipper, and producer, in comparison to network impacts, which ignore the economic considerations. Within the network impacts, NCHRP 732 discussed the infrastructure effects and developed an initial definition for diversion (Georgia Tech Research Corporation *et al.* 2012). Diversion analysis applies network tools to understand how networked infrastructure responds to increased cargo movement over specific segments of a network. After NCHRP-732, TRB produced *Making US Ports Resilient as Part of Extended Intermodal Supply Chains* (NCFRP-30), focusing on Hurricane Sandy and disruption to the freight network. NCFRP-30 developed a workflow to understand container disruption and how diversion of cargo from one port can have unintended knock-on effects for ports and infrastructures receiving increased container traffic, as represented in Figure 3.2.

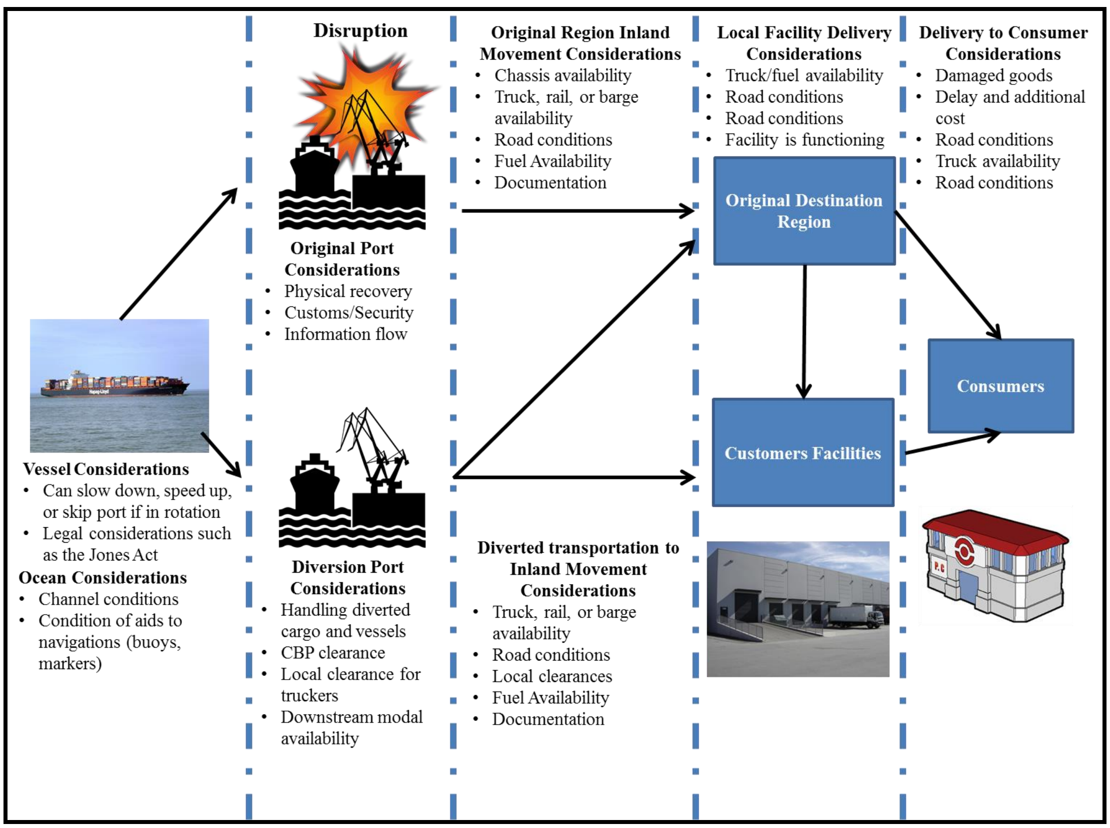

Figure 3.2: Import Container Diversion Workflow
Source: Adapted from Southworth et al. (2014) (with permission)

Figure 3.2 highlights the regulatory and operational challenges for diversion ports, including the need for extra vehicles and space to handle more containers. In the aftermath of Hurricane Sandy, containers diverted to ports required special stamps for their removal from the diversion port because that port was not on the bill of lading (CBP, 2012). NCFRP-30 also introduced the concept of modal flexing, the ability for other modes to pick up the slack for a mode affected by disruption (Southworth *et al.* 2014).

From both the Georgia Tech Research Corporation *et al*. (2012) and Southworth *et al.* (2014) reports, TRB commissioned a report in July 2016 to examine freight diversion and how such a methodology would affect freight transportation resilience. Part of the Request for Proposals included a review of existing practices for studying freight transportation resilience, mitigation strategies, spatial and temporal considerations, and identifying gaps in research (Rogers, 2016). The final report is not due until 2018 and it is unclear what type of diversion analysis, if any will be conducted as part of the research.

3.3 Critical Infrastructure Resilience

The critical infrastructure literature references and leans heavily on the term *resilience*. Recently, there has been a re-emergence of the resilience discourse. Resilience is not a new concept, rather, has resurfaced because of a contemporary sense of uncertainty and insecurity in society and the search for adaptation and survival (Christopherson, Michie and Tyler, 2010). Originally developed for ecological systems, resilience was the ability of systems to handle disturbance, adapt, and bounce back from a disruption to a new state (Hollings, 1973). Its application expanded to include the study of complex, adaptive systems to explain how systems handle uncertainty and shifts in systems resulting from adaptation to stresses on the system (Folke, 2006). While this dissertation does not seek to create a new definition for resilience, it is important to briefly survey the literature and explain how resilience applies within the freight transportation literature.

3.3.1 Defining Resilience

Over time, the resilience discourse grew and branched into different disciplines that accepted Holling’s definition and applied it to their particular circumstances. Building off the original definition, resilience has been described as a system characteristic, and is the result of the interaction of the system(s) involved (Timmerman, 1981). With roots in Ecology, it branched into Economics, Psychology, and Engineering. Within the Engineering context, much of the literature focuses on developing performance measures to analyze resilient behaviors for infrastructure systems. Particular attention concentrated on dimensions of resilience, including Robustness, Redundancy, Rapidity, and Resourcefulness "the 4 R's" (Bocchini *et al.* 2014; Bruneau *et al*. 2003).

The engineering definition of resilience expands upon Holling's original definition in two areas. First resilience comes from the communities using the infrastructure and not from the infrastructure itself (Bocchini *et al.* 2014). Second, the ability to recover is not solely an issue of physical recovery, but having the resources and means for fast, efficient, and effective recovery. The ability for infrastructure to recover is its ability to deliver a certain level of service even after a disruption (Bocchini *et al.* 2014). For the first consideration, this indicates that infrastructure resilience relies on other factors; be it the users of the infrastructure, the laws, or policies. Within freight transportation resilience, the acknowledgment that resilience is a result of the users, institutions, and management structures that rely on freight transportation illustrates this understanding.

In contrast to engineering, political science and policy literature explain resilience as the result of neoliberal policies (Joseph, 2013). From this perspective, scholars such as Anderson (2015), Sage, Fussey, and Dainty (2015), and Coaffee (2013) describe resilience as the result of externally imposed pressures that affect organization response and governance of those organizations experiencing pressure. Zebrowski (2013) summarized this change in framing of what resilience is, from an "ontologically discovered concept to an ontopolitical process" (Zebrowksi, p. 172, 2013).

3.3.2 Freight Transportation Resilience

Acknowledging the increased interest in resilience, research has begun to analyze what resilience means in transportation and freight. Wang (2015) compared transportation and ecological systems and recognized two similar characteristics; (1) the combination of land use and transportation systems are self-organizing and adaptive and (2) humans are a key component for developing adaptive capacity insofar as they are "objects of movement," contributing themselves to the precious time and energy required to make trips happen. Although focused on passenger transportation, similar metrics from those defined by Bruneau *et al. (*2003) are applicable for measuring resilience in transportation systems.

Freight transportation research has adopted similar definitions to those provided by the U.S. DOT and other federal agencies. Transportation resilience is defined as the "[transportation sector's] ability to resist, absorb, recover from, or successfully adapt to adversity or change in condition" (U.S. DHS, 2010). Freight resilience is the ability to provide reliable service when transportation encounters small disruptions and return to service quickly after large disruptions (Ortiz *et al.* 2009). In contrast to definitions focusing on physical performance, other definitions for freight resilience include the ability for the system to absorb the consequences of disruption, to reduce impacts of disruption, and maintain freight mobility (Ta, Goodchild, and Pitera, 2009). In contrast to the Transportation Sector Specific Plan, the definition developed by Ta, Goodchild, and Pitera (2009) recognized the importance of users and managing organization, in addition to the physical infrastructure. The acknowledgment of institutional stakeholders reinforced work by Caplice *et al.* (2008) that institutional and organizational actors are essential for fostering resilience, particularly in developing statewide freight resiliency plans.

Similar to the engineering literature on resilience, freight transportation research focuses on the development of performance metrics to measure resilience within the freight system. Faturechi and Miller-Hooks (2014) surveyed the existing literature on infrastructure performance during and after disasters and developed a list of common performance indicators as represented in Table 3.5. While some of the measures in Table 3.5 are the same as the "4 R's" developed by Bruneau *et al*. (2003), other measures included the purported vulnerability of the system and the flexibility of the system to adapt to changes.

Table 3.5: Common Performance Measures for Measuring Transportation in Disasters

Measure	**General Definition**
Risk	Combination of probability of an event and its consequences in terms of system performance
Vulnerability	Susceptibility of the system to threats and incidents causing operational degradation
Reliability	Probability that a system remains operative at a satisfactory level post-disaster
Robustness	Ability to withstand or absorb disturbances and remain intact when exposed to disruptions
Flexibility	Ability to adapt and adjust to changes through contingency planning in the aftermath of disasters
Survivability	Ability to withstand sudden disturbances to functionality while meeting original demand
Resilience	Ability to resist, absorb, and adapt to disruptions and return to normal functionality

Source: Faturechi and Miller-Hooks (2014)

A problem with the performance-measure discourse in transportation research is the multiple definitions and interchangeable use of performance measures. An example of this is interchangeability problem is with the robustness and redundancy performance measure. To be a robust system, according to Faturechi and Miller (2014), the system must be able to absorb disturbances and remain intact, manifested through multiple routes through a network, regardless of the mode of transportation used. A similar definition is applied to redundancy as represented in work by Adams, Bekkem, and Toledo-Durán (2012). Adams, Bekkem, and Toledo-Durán (2012) studied the impact of blizzards on truck disruptions in Wisconsin and described redundancy as the availability of alternative modes of transportation, in addition to alternative routes. In another application of the robustness performance measure, Sullivan *et al.* (2010) defined robustness based on the robustness of the network as a whole, similar to Faturechi and Miller-Hooks. However, Sullivan's redundancy definition focused on the number of available routes for a particular mode, departing from Adams, Bekkem, and Toledo-Durán (2012) definition. Trying to avoid this confusion, Southworth *et al*. (2014) renamed robustness to *modal flexing* in an effort to the highlight the ability for multiple modes to shoulder additional traffic load if one mode experiences disruption. This research will apply the modal flexing definition developed within Southworth *et al.* (2014) as it cleanly illustrates how different modes handle increased traffic because of a change in a law that affects other modes of transportation.

3.4 Autonomy and Emergence: The Challenge facing Systems Thinking

Various literatures use the word *system* to describe the interaction and behavior of parts, wholes, and the relationship of such wholes to their surroundings. The Systems Thinking and General Systems Theory literature provide a foundation for much of the literature discussed so far, especially for transportation. A dominant view in transportation research is that transportation is a system. As the discussion so far illustrates, the complexity with individual systems becomes magnified and complex when these systems interact. These interactions and complexities demonstrate that traditional Systems Thinking does not adequately account for multiple, independent systems interacting and the resulting behavior that emerges from such interaction. This section explores the existing literature on systems thinking for transportation and the law, with Section 3.4.3 rebutting the existing framework and calling for an alternative.

3.4.1 Transportation: A Traditional Systems View

Transportation research describes transportation as a system. The epistemological framing of transportation as a system traces back to early work of Lieb (Dodder, and Mindell, 2000). Lieb's original conception of transportation systems included the physical guideways and the vehicles using the guideways to travel from an origin to a destination (Dodder and Mindell, 2000). Subsequent to Lieb, Manheim (1979) expanded the transportation system definition to include the movement of goods and people. This expansion to include activity recognized a relationship between the physical transportation infrastructures (technical system) with activity (socio-economic systems) (Manheim, 1979). The result of the interaction of the technical system and activity is the flow of people and goods.

The definition of a transportation system did not stop with Manheim's introduction of activity and flow. The application of networks and network science to transportation increased the quantitative analytical capacity for analyzing flow (Morlok, 1978). This increased analytical rigor replaced the abstraction of vehicles, activity, and flow, with networks providing an analytical structure for representing and studying how goods and people move. Given the development of sophisticated analytical techniques and flow, transportation systems research gained acceptance over time, becoming more complex with further additions to what is part of a transportation system.

With increasing complexity for what constitutes part of a transportation system, recent research has developed analytical frameworks for organizing parts of the transportation system. In his book, *Introduction to Transportation*, Sussman developed a dichotomy for those elements that are "internal" to the transportation system and the "external" factors that affect the internal elements of the transportation system (Sussman, 2000). Internal components of a transportation system include the physical components and the operating plans and operators, as illustrated in Figure 3.3.

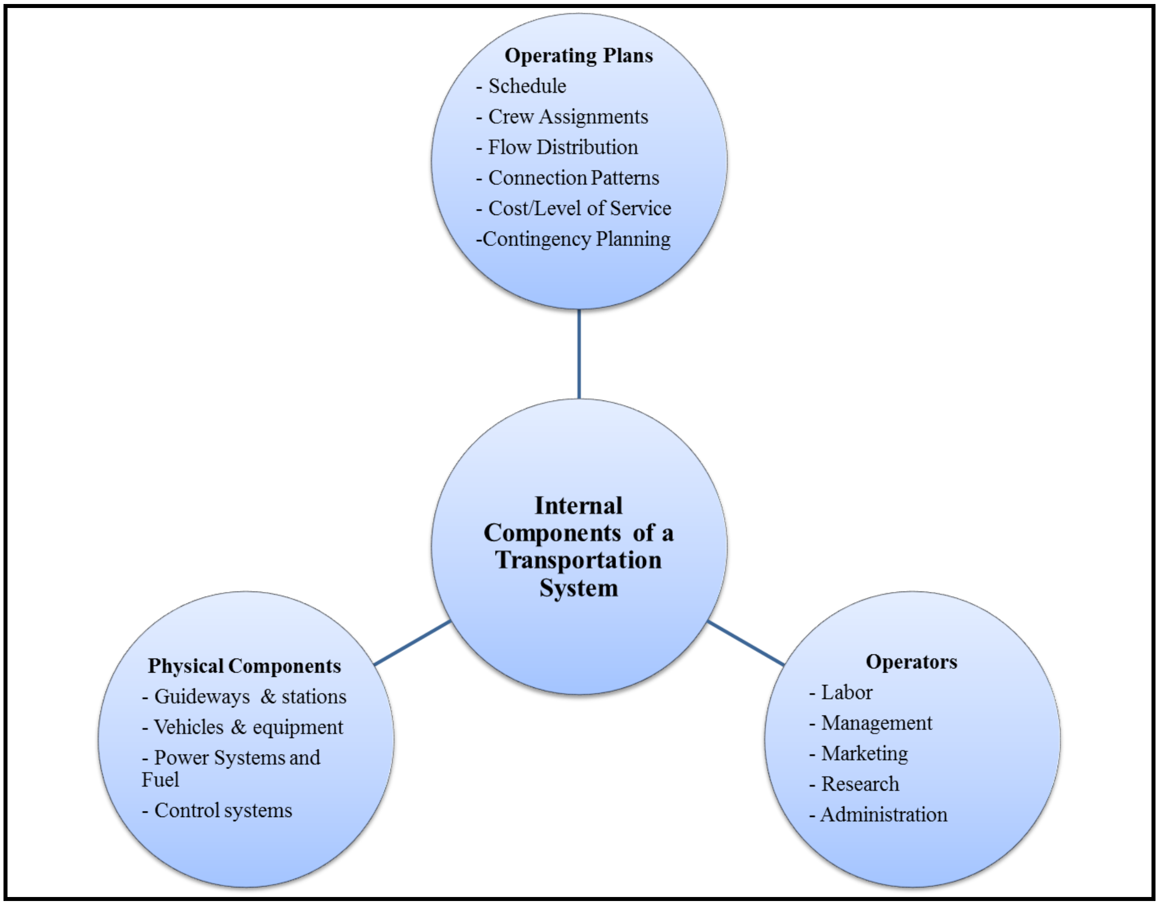

Figure 3.3: Internal Components of a Transportation System
Source: Adapted from Sussman (2000)

The other portion of Sussman's dichotomy for transportation systems includes an external component. The internal components, those physical infrastructures, operations, and operators, are affected by external forces, including government regulations, competition between different transportation carriers, the financial community, and pressure from stakeholders and the public (Sussman, 2000). Although the external components represented in Figure 3.4 recognize the increasing complexity with transportation systems, it does not adequately address how external factors affect the internal components.

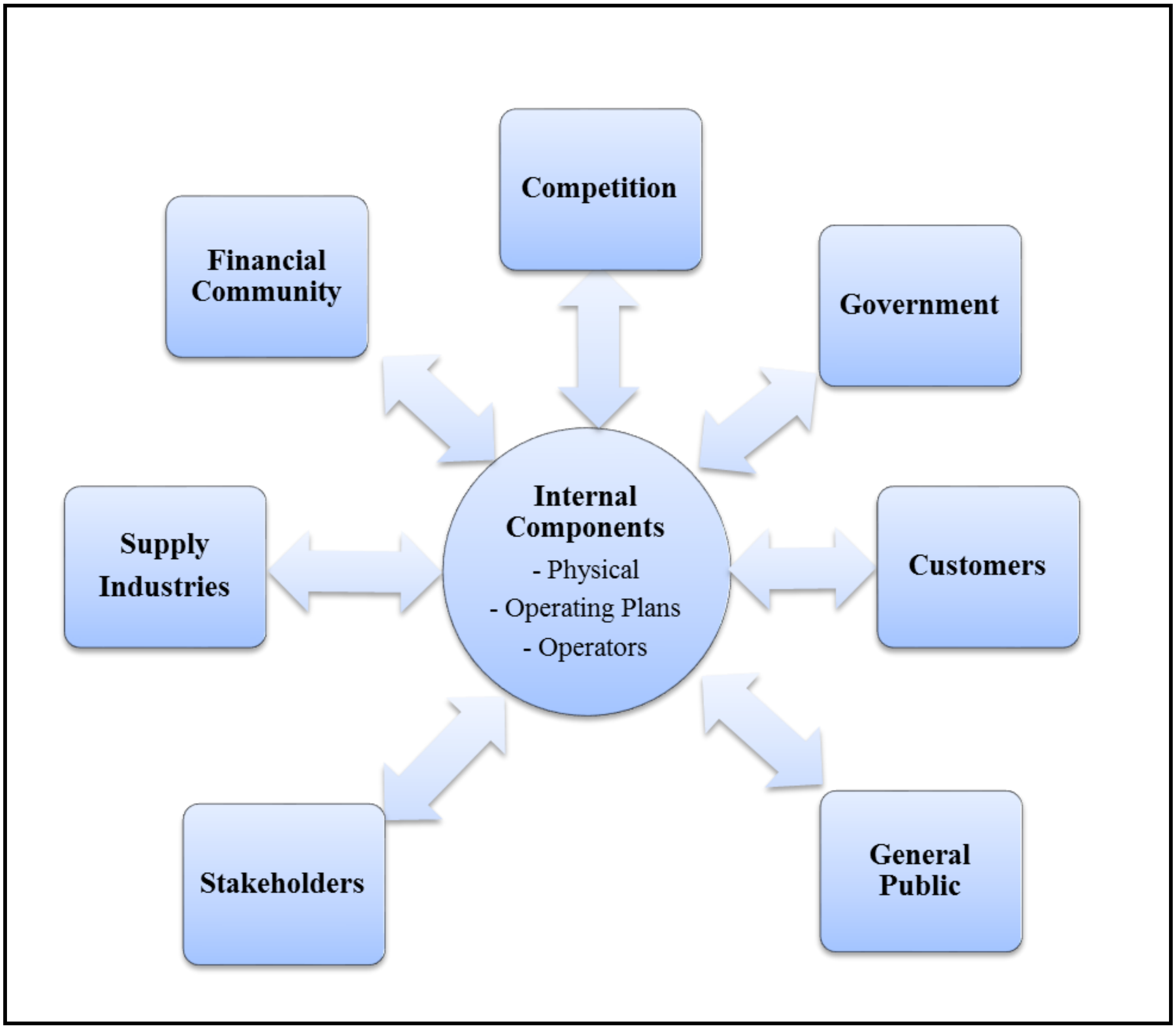

Figure 3.4: The Transportation System Dichotomy
Source: Adapted from Sussman (2000)

This approach to describing transportation is dominant in the engineering domain; however, it does pay some attention to the law and policy drivers that play a role in the operation of transportation.

In an attempt to develop a more complete representation for understanding transportation and its relationship to the external factors described by Sussman (2000), other representations within the Systems Thinking framework try to explain the relationship between the technical sphere and what some describe as the "institutional sphere" (Sussman, 2000). The concept of CLIOS (Complex, Large-scale, Interconnected, Open, Sociotechnical) Systems tries to develop an approach to represent and analyze the relationship between the technical, "physical sphere" and the “institutional sphere” (Sussman *et al.* 2007; Sussman, Sgouridis, and Ward, 2005). Sussman *et al*. (2007) describe what the individual components of CLIOS mean:

- **C**omplex: When a system is composed of interrelated components, these relationships are imperfectly known, resulting in complexities that vary in time, space, and scale,
- **L**arge-Scale: Systems which are large in magnitude and cover a large geographic area,
- **I**nterconnected: One system is interconnected or interdependent on another system. An example of this interdependency is the relationship between the transportation system and the energy system,
- **O**pen: The inclusion of social, political, and economic aspects, and
- **S**ociotechnical: Recognize the interrelationship between society and technology.

The CLIOS framework recognizes varying complexities involved with studying transportation, as described in Table 3.6, ranging from spatial, temporal, to scalar challenges.

Table 3.6: Foundation Complexities of CLIOS

Structural Complexity (Combinatorial Complexity)	A system that consists of a large number of interconnected parts.
Behavioral Complexity (Dynamic Complexity	Prediction of system outputs or behaviors is difficult.
Nested Complexity	A relationship exists between a physical domain, which is embedded within an institutional domain (or sphere).
Evaluative Complexity	Stakeholder input and valuation of system performance

Source: Sussman et al. (2007)

For this research, the concept of *Nested Complexity* is of particular interest because it studies the relationship between the technical and institutional spheres. Nested complexity represents the presence of a physical, technical domain embedded within an institutional sphere (Sussman *et al.* 2007). Both the institutional sphere and the physical domain contain interactions within their respective spaces, but explanations are limited within the CLIOS framework. Figure 3.5 represents the concept of Nested Complexity

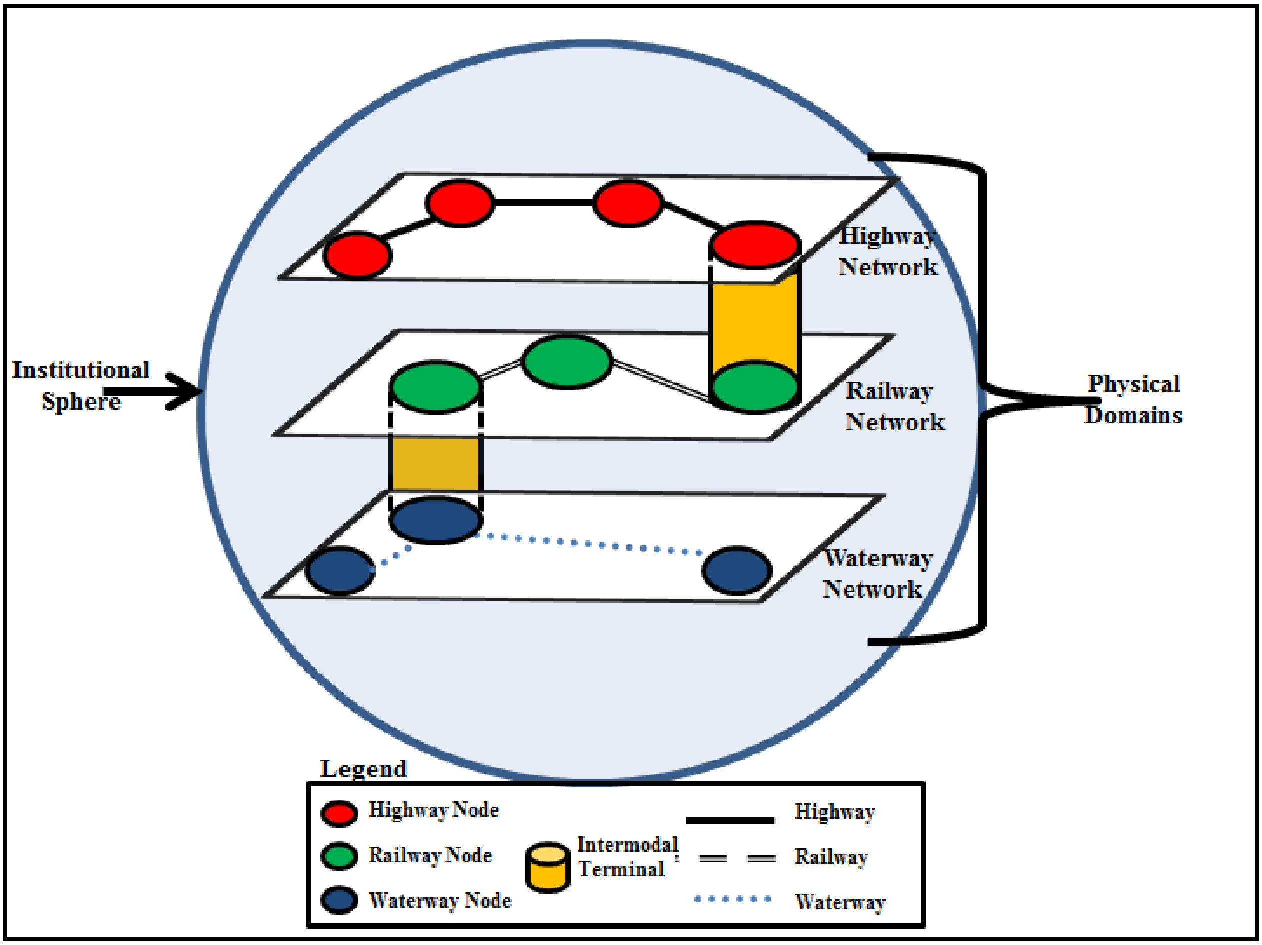

Figure 3.5: Nested Complexity represented in CLIOS
Source: Adapted from Sussman et al. (2007)

Within Figure 3.5, each of the physical transportation networks are represented on different "plates." Each plate contains different colored dots, representing nodes within that particular network (highway intersections, train stations, seaports, intermodal terminals, etc.). The intermodal terminals connect different plates when two modes overlap their activity at the same terminal. These physical networks are embedded within a larger "institutional space." Along the boundary of the institutional space, different agencies interact with the different physical networks. Such interactions are governed by statutes or regulations, represented in Figure 3.6 with arrows.

While providing a visual representation for the interaction between the institutional and technical spheres, the primary purpose of CLIOS is to provide a policy framework to analyze how policy interventions affect transportation. Through a twelve-step process, users of the CLIOS process inventory the infrastructure in the physical domain, identify specific policies for implementation, establish performance measures, evaluate strategies, and review implementation

(Sussman *et al.* 2007). Previous studies by Sussman, Dodder, and McConnell (2004) and Sgouridis (2003) used the CLIOS framework to assess the impact of air pollution policies in Mexico City and Malaysian maritime transportation respectively, though its application past these two studies is limited.

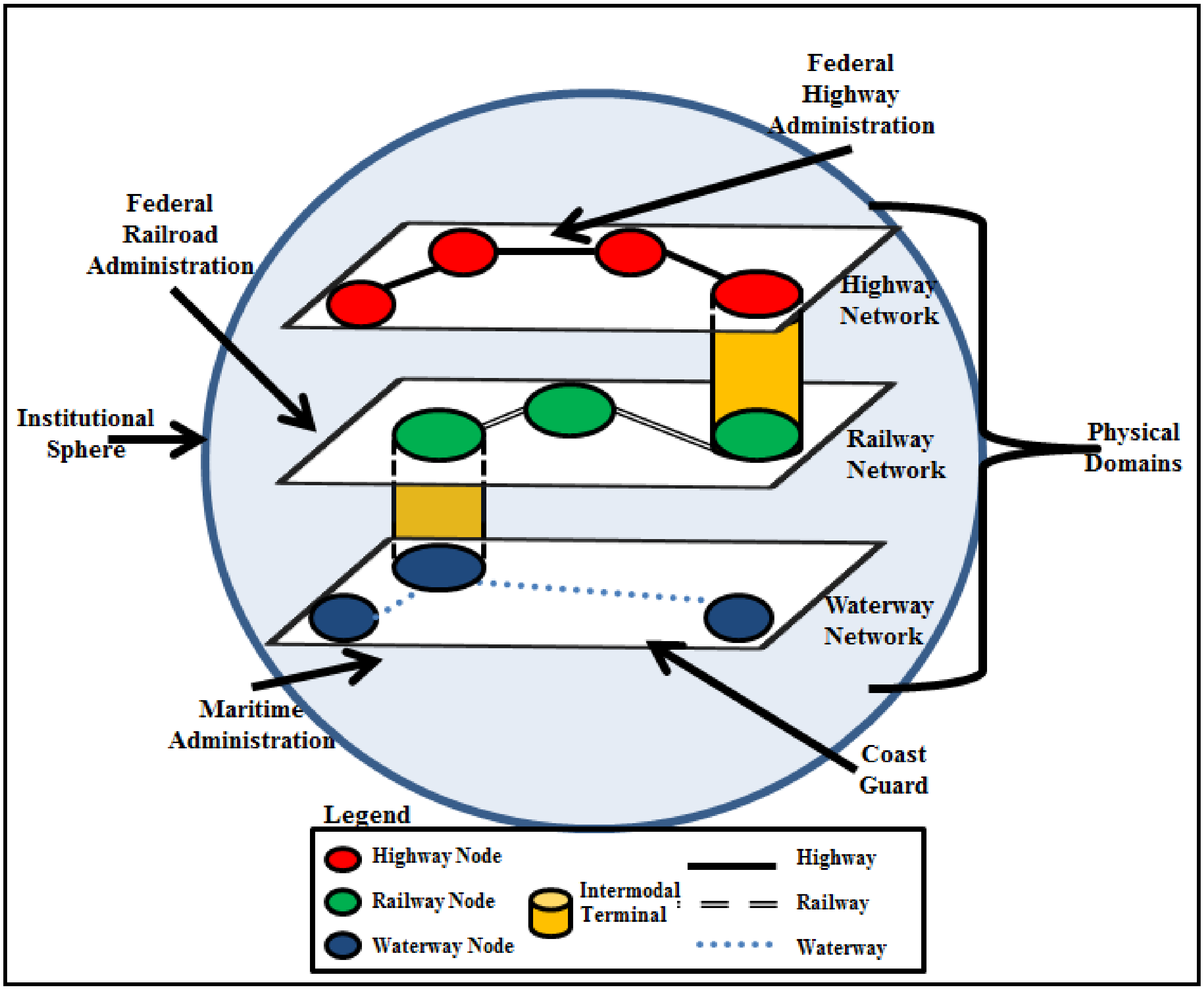

Figure 3.6: Institutional domain interacting with physical domain
Source: Adapted from Sussman et al. (2007)

Even though previous studies used CLIOS to frame questions similar to the one posed in this dissertation, CLIOS is only a process. It is an analytical technique for understanding a problem, with limited advancement in an ever-changing conceptualization of complexity, especially in transportation studies (Hall, 2005). In the study conducted by Dodder, Sussman, and McConnell (2004), the study team's analysis of the institutional domain focused on the orientation of which agencies affected specific infrastructure systems in Mexico City. Merely orienting which agencies affect which infrastructure does not address complex administrative interactions within the institutional sphere. The "lines" that connect an agency to an infrastructure do not sufficiently describe how that agency influences the infrastructure. Devoid from the analysis is the recognition that law itself is a system that underpins the institutional sphere. In his critique of the CLIOS process, Hall (2005) argued the focus on technical systems does not acknowledge the complexity within social systems and how intermediate structures such as institution, affect the physical domain.

3.4.2 Law as a System and Autopoiesis

Legal theorists have also applied Systems Thinking to understanding the Law. In his book, *The Concept of Law*, H.L.A. Hart described the conditions that form the foundation for what constitutes a Legal System. For a Legal System to exist there must be the "union of two minimum conditions, the Primary rules of obligation of duty and Secondary rules of recognition, change, and adjudication" (Payne, 1976, p. 288-289). Primary rules are those rules that impose duties on officials and citizens, whereas Secondary rules confer powers on public or private citizens (Payne, 1976). For Hart, Primary rules are necessary for the existence of a Legal System, while the absence of Secondary rules would influence the behavior with the system. Specifically, the absence of Secondary rules increases uncertainty and imposes a static nature on the development of dynamic behaviors (Payne, 1976). Finally, the absence of these Secondary rules generates inefficiencies within society because there would be no agencies or individuals conferred with the power to adjudicate conflict between individuals (Payne, 1976).

The interaction between constituents described by Hart (1961) in the context of Secondary rules reflect the fluidity of law and social structures can create feedback for changes or creation of new laws. Timmerman (1981), citing the work of Talcott Parsons (1966), explained that the interactions themselves can manifest legal codes and regulations that bind those constituents that make up the system. Law and policy is endogenous to a system and not so much an environmental factor as articulated by Rinaldi, Peerenboom, and Kelly. (2001). Easton (1966) argued that within a system, there is a sub-system, which is a regulator or control sub-system within the system that acts as an authority to manage and control the overall system. Easton acknowledged a political and, by extension, legal order and rationality that is needed for the system to function.

In contrast to views such that law is an open system, susceptible to change from social, political, and economic pressures, a contrasting view of *Autopoiesis* suggests that the law is not an open system, rather a closed system, devoid of the norms and rules described previously. An autopoietic system is self-producing and closed off from other systems surrounding it (Mattheis, 2012). Autopoietic systems differentiate themselves from surrounding systems, with those surroundings classified as environmental, with limited influence on the system itself. The concept of closed system, as described by Mattheis, stresses the need for systems to define clear boundaries between their internal parts and the environment, with limited to no interaction between the system and the environment.

In the context of autopoietic legal systems, work by Niklas Luhmann heavily influenced the systems view within legal theory. Luhmann's view of legal systems departed from "mainstream systems theory" in his belief that the law is not a system of rules and laws, open to pressures, rather, the legal system is an autopoietic system, separate and apart from other systems (Luhmann, 1991). Although the law is autopoietic, its influence on social systems is possible base on the concept of *Structural Coupling*. Structural Coupling allows autopoietic systems to "bridge" between the system and the environment, allowing for the transmission of expectations and norms between the system and its environment (Mattheis, 2012). Structural Coupling does not affect the autopoietic nature of a system because the system can choose to include or exclude those influences from the environment (Mattheis, 2012).

The concept of an autopoietic law system, structural coupling, and differentiation provide strong arguments for defining law as a system. However, Luhmann's work and Mattheis focus the analysis of legal systems on how social systems affect the law and vice versa. The legal theory literature focuses primarily on the interaction of law and social systems, not law and technical systems such as transportation. While Luhmann's work in Law and Systems Thinking is a cornerstone for social science research and legal theory, it does not address relationships beyond the social system. Additionally, under Luhmann's structural coupling argument, the law, as a legal system can exclude feedback from the use of infrastructure systems (*e.g.*, if a particular legal or policy intervention affects transportation performance, the law and policy system do not need to accept such feedback and can continue to operate as though no feedback existed). This line of argument would be in conflict with Sociotechnical Systems thinking and the CLIOS process. This presents a conceptual gap in understanding the relationship between the law and technical systems such as infrastructure.

3.4.3 Critique of Systems Thinking

While CLIOS and other Sociotechnical System (STS) frameworks within Systems Thinking try to capture the complexity interlaced within transportation and the law, these approaches illustrate the challenge of using a systems approach to study transportation. The parts, spheres, and domains cannot be viewed as mere parts to a greater whole; these parts have independence and exert control over their own functionality. To ignore their own behavior as merely subservient to a greater whole does injustice to the intrinsic importance of these behaviors. Given these shortcomings, the next section describes an alternative framework for studying transportation, including its relationship with law and policy.

To classify transportation as a system assumes that units, parts, and components that make up the whole system lack autonomy. Perrow's (1999) research into high-risk technologies stressed the hierarchical nature of systems (parts → unit → subsystem → system). Recognizing dynamic systems and the close coupling of multiple systems, Perrow's work stressed that parts of a system do not function on their own if they are removed from the system. Using the example of nuclear reactors, Perrow explained that a water valve by itself does not have utility, but placed into a larger system, its utility is in its ability to regulate water flow and provide adequate coolant for regulating heat within a nuclear reactor (Perrow, 1999). This view of systems aligns with the work of von Bertalanffy (1972) who stressed the nature of systems and the close relationship between parts and wholes. Complexity and its impact on understanding transportation as a system raises the question of whether the traditional systems view adequately accounts for dynamic, closely coupled systems, that through their interaction develop emergent, unforeseen behaviors that the original systems did not exhibit.

3.5 An Alternative: System of Systems Thinking

In response to increasingly complex systems, their interactions, and the need for a more robust conceptual framework for understanding complexity, research within the last twenty years addressed some of the issues mentioned in the previous sections. One of the initial critiques against Systems Thinking was the ability for highly coupled systems to exert independence from one another if these couplings disappeared. Using examples from Integrated Air Defense and Intelligent Transportation Systems, Maier (1998) began to develop an alternative explanation for behaviors of highly coupled systems. Where systems maintained *Operational Independence* and *Managerial Independence* of their components and systems, they were a System of Systems

(SoS) rather than a pure System (Maier, 1998). Maier's departure from a traditional System and a System of Systems relied heavily on the concepts of Operational and Managerial Independence. For a system to exhibit Operational Independence, the system must be able to operate independent from the System of System it supports (Maier, 1998). In contrast, Managerial Independence occurs when the disassembled system "not only can operate independently, [it does] operate independently" (Maier, p. 271, 1998). For Managerial Independence, the Systems being assembled come together as a matter of circumstance, but can exist independently should that circumstance change.

3.5.1 Comparing Systems Thinking and System of Systems Thinking

Maier's (1998) defines a System of Systems as an assemblage of component systems with two conditions. First, the components fulfill valid purposes in their own right and continue to operate and fulfill those purposes if disassembled from the overall system (i.e., Operational Independence). Second, the components can be managed for their own purposes rather than the purposes of the whole (i.e., Managerial Independence). While this work started to frame System of Systems, it did little to provide a stark contrast to traditional Systems Thinking. This is where work by Boardman and Sauser began to bridge the theoretical differences between the two streams of thought. "Systems thinking for too long [was] preoccupied with interior design, with the parts and their relationships[;] meanwhile, exterior design, the context for the whole and all that it means in terms of influences, ownerships, and adaptations have sadly been neglected or reduced to statements that the determine the system's interior design" (Boardman and Sauser, p. 1, 2006). While system design is important, the concern of understanding how systems survive in "uncertain environments perpetually changing in unknowable ways," was of equal importance in the System of Systems analysis (Boardman and Sauser, p.1, 2006).

While Maier's initial differentiation between a system and a System of Systems proved useful in starting to create space between the two frameworks, the System of System concept required more refinement to capture the uncertainty and attributes discussed by Maier (1998) and Boardman and Sauser (2006). In addition to Managerial and Operational Independence, Boardman and Sauser (2006) added five other behavioral attributes to distinguish a System from a System of Systems. Although not explicitly building off of Maier's Managerial and Operational Independence, Boardman and Sauser focus on; (1) Autonomy, (2) Belonging, (3) Connectivity, (4) Diversity, and (5) Emergence, which are distinguishable when discussing systems and System of Systems. Within Table 3.7, the five attributes are compared between the system view and the System of Systems view.

Table 3.7: Comparing System and System of Systems Attributes

Attribute	System	System of Systems
Autonomy	Autonomy is ceded by parts in order to grant autonomy to the system	Autonomy is exercised by constituent systems in order to fulfill the purpose of System of Systems
Belonging	Parts are akin to family members; they did not choose themselves but came from parents. Belonging of parts is in their nature	Constituent systems choose to belong on a cost/benefit basis; also in order to cause greater fulfillment of their own purposes, and because of belief in the System of Systems supra purpose
Connectivity	Prescient design, along with parts, with high connectivity hidden in elements, and minimum connectivity among major subsystems	Dynamically supplied by constituent systems with every possibility of myriad connections between constituent systems, possibly via a net-centric architecture, to enhance System of Systems capability
Diversity	Managed – i.e., reduced or minimized by modular hierarchy; parts' diversity encapsulated to create a known discrete module whose nature is to project simplicity into the next level of the hierarchy	Increased diversity in System of Systems capability achieved by released autonomy, committed belonging, and open connectivity
Emergence	Foreseen, both good and bad behavior, and designed in or tested out as appropriate	Enhanced by deliberately not being foreseen, though its crucial importance is, and by creating an emergence capability climate, that will support early detection and elimination of bad behaviors

Source: Boardman and Sauser p.4 (2006)

Similar to the work of Maier and the application to Integrated Air Defense and Intelligent Transportation Systems, the application of System of Systems thinking expanded to other domains, including management and urban transportation optimization. Through case study of the Yellow Cab in New York City, Gorod *et al*. (2008) highlighted how a System of Systems captured the behavior of Yellow Cab operation in New York and provided a concrete example of how a System of Systems framework applies to understanding complex problems beyond what systems thinking can be applied to. DeLaurentis (2009) also applied a System of Systems approach to transportation, but focused on how elements of airplane systems are a System of System rather than a System.

Within the last two decades, the System of Systems frame has been applied to issues of maritime transportation. Harrald, Stephens, and vanDorp (2004) described seaports as a System of Systems. In particular, the authors identified the role ports play in global supply chains for multiple commodities and the variety of stakeholders involved in the operation and security of seaports. Of particular interest was the explicit acknowledgment of the institutional actors and their relationship to the physical infrastructure of the seaport.

While Harrald, Stephens, and vanDorp's work on port security provided a first glimpse into the application of System of Systems thinking to maritime transportation, work by Mansouri, Nilchiani, and Mostashari (2009) applied System of Systems thinking to the whole Maritime Transportation System (MTS), including ports. Studying MTS from the perspective of a System of Systems provides more flexibility in analyzing how resilient the MTS is to disruptions (Mansouri, Nilchiani, and Mostashari, 2009). This first iteration on studying the MTS through a System of System's perspective laid the foundation for later work by the same group of authors that focused on the individual behaviors described in Table 3.7.

Whereas the previous work by Mansouri, Nilchiani, and Mostashari (2009) considered the use of System of Systems thinking to study resilience, the authors did not adequately explain how the work of Boardman and Sauser (2006) integrated into their work for the whole MTS. In subsequent work, Mansouri *et al.* (2009) integrated Boardman and Sauser's work and applied it to the MTS. In the first stage of their analysis, the authors inventoried and categorized the MTS by visualizing the different elements of the MTS as represented in Figure 3.7. Within their representation of the MTS, the authors developed five major domains, (1) Ships, (2) Ports, (3) Users, (4) Waterways, and (5) Intermodal Connections. From there, each domain is subsequently broken down into constituent systems. It is important to note that within the Intermodal Connection and Waterways domain, the authors explicitly call the units systems, acknowledging their operational and managerial independence outside the MTS.

After developing the representation shown in Figure 3.7, Mansouri *et al.* (2009) proceeded to integrate the five attributes developed by Boardman and Sauser (2006) into the MTS. For each attribute, Mansouri and his collaborators outlined how the autonomy, belonging, connectivity, diversity, and emergence manifested themselves through the various facets of the MTS. For example, with respect to autonomy, elements within the MTS could stand alone if the MTS disappeared; the rail system would still operate, as would the aviation and trucking industry. From the perspective of the legal system, if the MTS disappeared, the legal system would not disappear, but would continue to function independently. The autonomy attribute represents an evolution from Maier (1998) to Boardman and Sauser (2006) to an application in the transportation space.

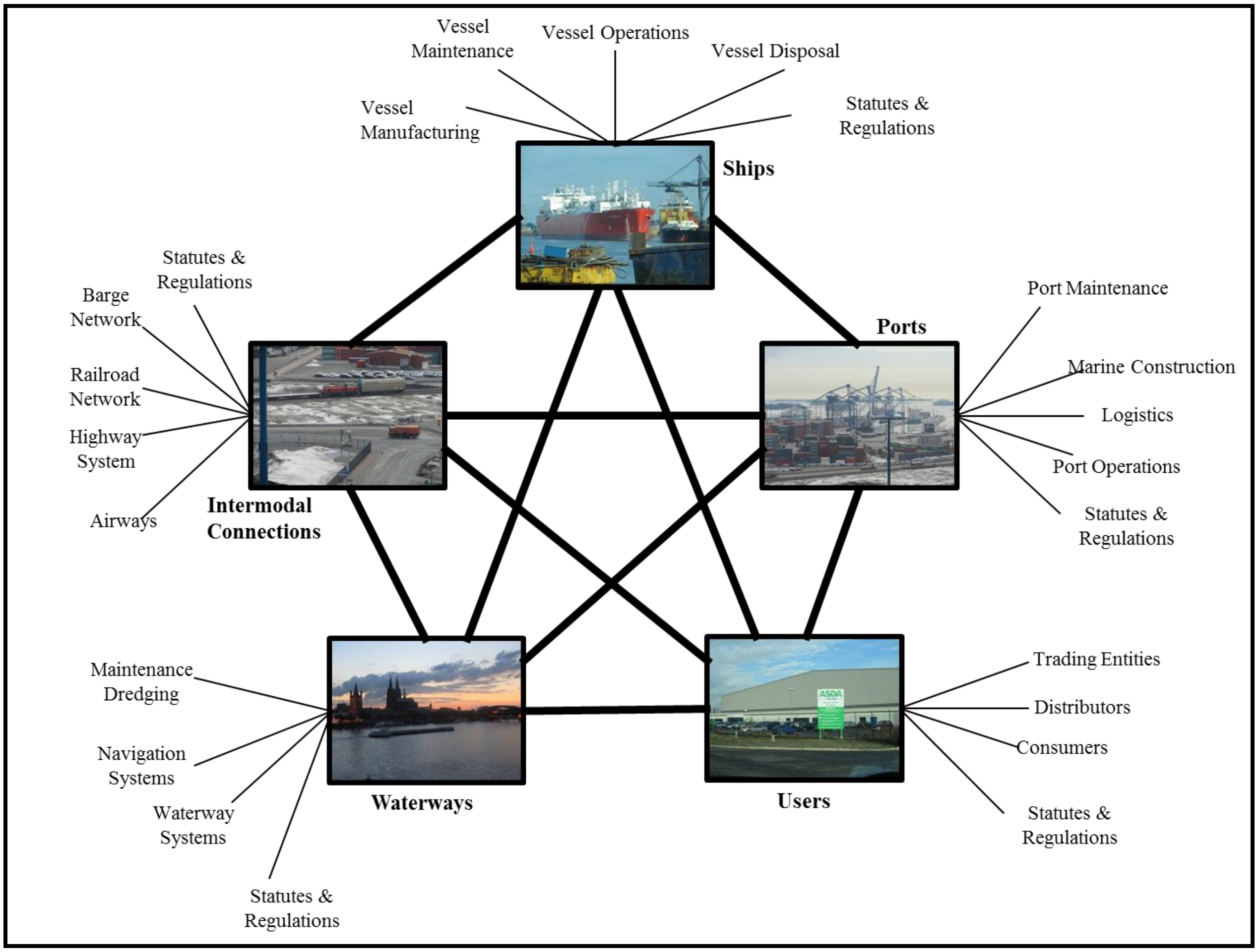

Figure 3.7: A System of Systems view of the Maritime Transportation Systems
Source: Adapted from Mansouri et al. (2009). Photo credit: M. Fialkoff (2011)

For the attribute of belonging, Mansouri *et al.* (2009) explicitly acknowledged relationships between agencies and the coordination required between the private and public sector operators and agencies. Attributes such as connectivity and diversity highlight the heterogeneous nature of the various systems within the MTS. These two attributes in particular emphasize the importance of network-centric approaches to studying the relationships between physical infrastructure and the respective laws and institutions that govern them. For the fifth attribute, emergence, Mansouri *et al.* (2009) discussed how resilience is a type of emergent behavior. Within their analysis, they determined that the ability for MTS to adapt to unforeseen changes can help develop their adaptive capacity and resilience overall.

In comparing the emergence concept between Systems and System of Systems, Boardman and Sauser (2006) also associate directionality to the effect of an emergent behavior on Systems and Systems of Systems. For Systems, emergent behavior can be good or bad, with such dichotomy subject to experimentation (Boardman and Sauser, 2006). Within the System of

Systems view, emergence only enhances a System of Systems through its ability to adapt to uncertainty and is reactionary to preserve functionality.

3.5.2 System of Systems Architecture

In the development of the System of Systems frame and approach, a reoccurring issue relates to the *architecture*, or design of a System of Systems. Maier's work began to address the issue of architecture with the ability for component systems to have Managerial and Operational Independence, with further work by Mansouri *et al.* (2009). The question of architecture for complex systems is important, especially when considering the role and expression of the law within a System of System discussion.

Discussed in Section 3.2, the critical infrastructure literature is limited for explaining the relationship between law and critical infrastructure. The literature describes critical infrastructure as a System of Systems (Ottens *et al.* 2006). The role of the law and policy are environmental factors, not part of the system, rather a factor to be internalized (Rinaldi, Peerenboom, and Kelly, 2001). Although the primary focus of their work is mapping the various interdependencies that exist between various critical infrastructures, Rinaldi, Peerenboom, and Kelly (2001) placed law and public policy effects on infrastructure as environmental factors that the infrastructure system must conform to. While Rinaldi, Peerenboom, and Kelly's (2001) description attempts to create a relationship between infrastructure and law as a system interacting with its environment, it does not adequately express the intricacies of law. In work by Maxwell (1867) and his discussion of Governors as system regulators, it is clear that the law is not merely an environmental factor, but engrained into the central tenets of the system, if not a system itself. Even though the work of Maxwell focuses on natural laws of motion and mechanical systems having internal controls (Governors) that prevent the system from behaving out of its operating parameters, the analog that law is part of a system and not merely an environmental factor provides a framework for conceptualizing law as a system.

This concept is further developed when discussing system architecture and the development of systems. In their work, entitled *The Influence of Architecture in Engineering Systems*, Crawley *et al.* (2004) explained that within every system, there is architecture, which is an arrangement of entities and relationships. Relationships can be structural, behavioral, or collaborative, providing context and further definition (Jaakkola and Thalheim 2010). Levi (1999) defined the various architectures as illustrated in Table 3.8.

Table 3.8: System Architecture Typologies

Architecture Typology	***Description***
Functional	A partially ordered list of activities or functions that are needed to accomplish the systems requirements
Physical	A node arc representation of the physical resources and their interconnections
Technical	A elaboration of the physical architecture that comprises a minimal set of rules governing the arrangement, interconnections, and interdependence of the elements such that the system will achieve the requirements
Dynamic Operational	A description of how the elements operate and interact over time while achieving the goals

Source: Levi (1999)

3.5.3 A Framework for Studying the Jones Act and Freight Networks

This research uses a System of Systems approach to analyze how relaxing the Jones Act affects the freight transportation network in the aftermath of a disruption. In contrast to traditional Systems Thinking, a System of Systems framework provides a robust platform to understand interacting systems. Recognizing Luhmann's (1991) and Arnold and Gunderson's (2013) work that identify the law as a separate and independent system from others, the System of Systems framing preserves this independence.

Given the multiple systems involved in understanding the influence of the Jones Act on freight transportation networks, a visual representation is required. An example of a visualize representation of a System of Systems is provided by Figure 3.7, which describes the Maritime Transportation System of Systems. The various systems within the System of Systems include Ships, Users, Intermodal Connections, Waterways, and Ports (Mansouri *et al.* 2009). Within this illustration, laws and statutes are parts of the individual systems. Although only one example of representing the law and its relationship to the systems described, it is deceptive in its representation. This representation does not recognize the law's position as an independent system compared to the systems it governs. Another way of representing the law and its relationship to the components described by Mansouri *et al.* (2009) is illustrated in Figure 3.8. In contrast to Figure 3.7 where the law is part of each of the systems, Figure 3.8 creates a distinct box that represents a legal system.   In this representation, law and policy interconnects with the different elements of the Maritime Transportation System of Systems.

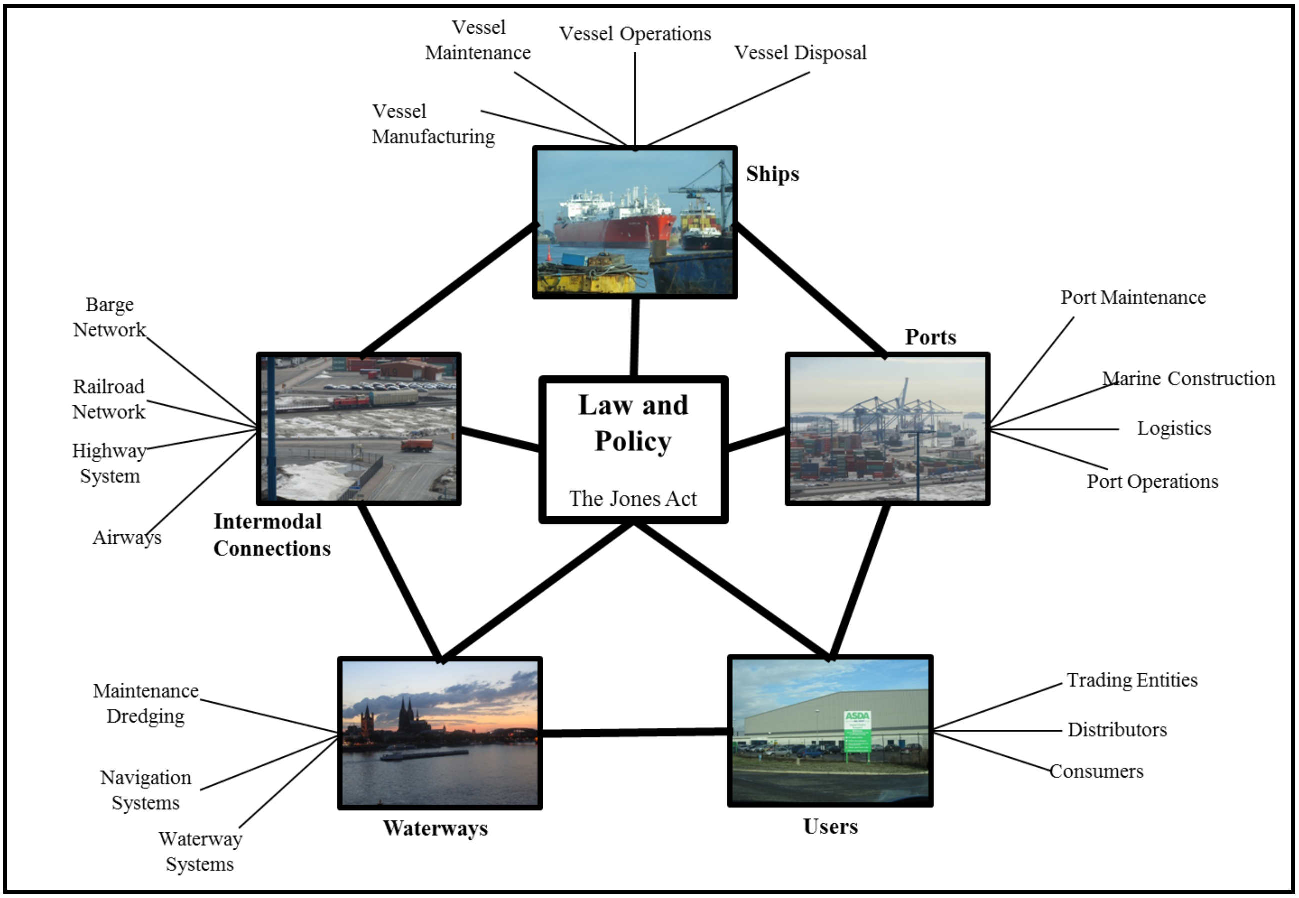

Figure 3.8: Modified System of Systems Framework for Maritime Transportation
Credit: M. Fialkoff (2017) as modified from Mansouri et al. (2009)

Even though Figure 3.8 creates a separate box representing law and policy as a separate system from the others, it is a two-dimensional representation and still does not accurately represent spatial orientation and the variety of laws that affect the Maritime Transportation System of Systems. Figure 3.9 converts the two-dimensional representation of Figure 3.8 into a three-dimensional representation, where the law and policy system is above the maritime transportation elements. This creates a separation between the law and policy system and the physical elements. The dashed blue lines illustrate the connectivity between the different physical components within the Maritime Transportation SoS, with the black lines connecting each of the physical systems to a law and policy system that governs these individual systems.

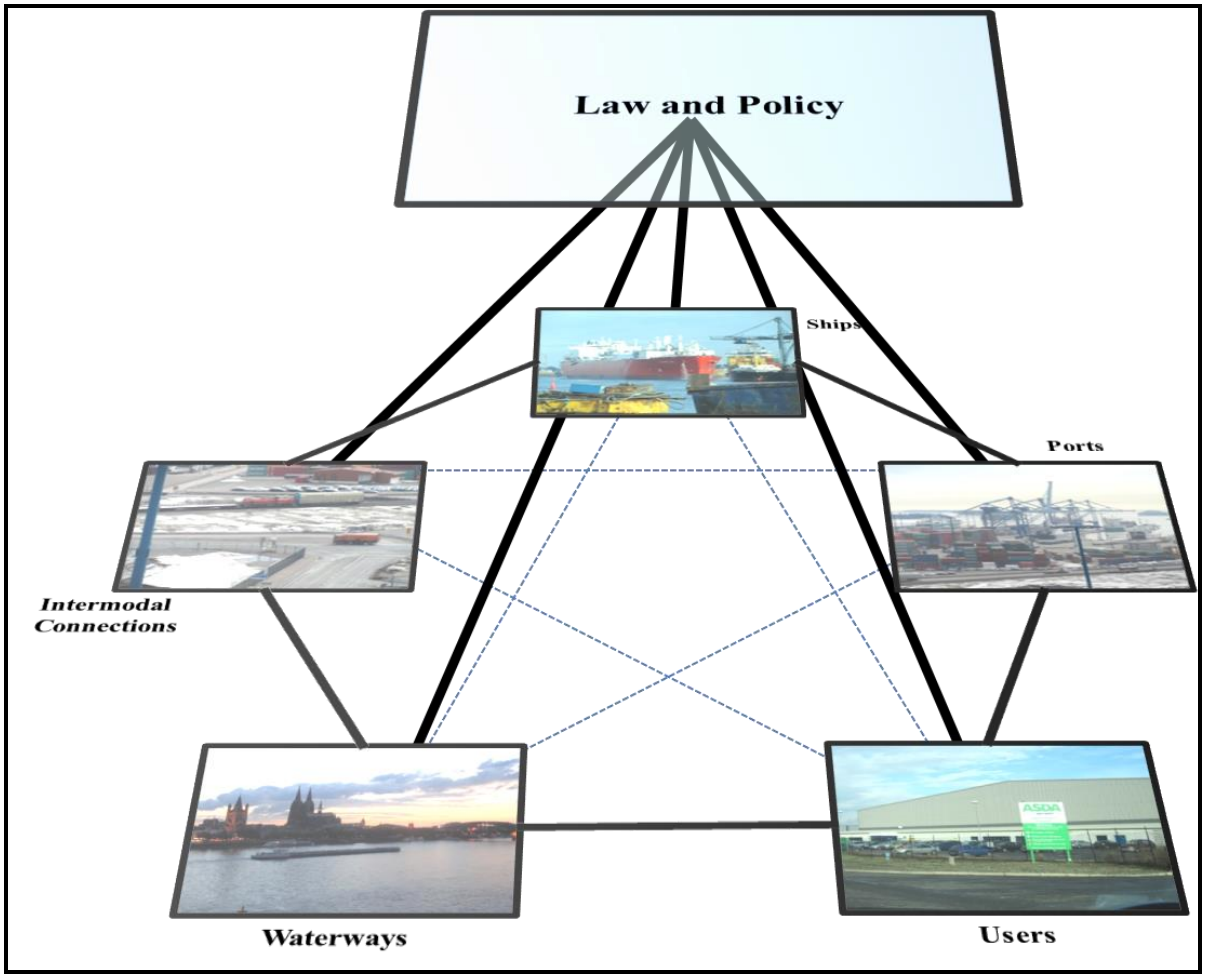

Figure 3.9: Three-dimensional representation of Law and Policy in MTS SoS
Credit: M. Fialkoff (2017) as modified from Mansouri et al. (2009)

The evolution from Figures 3.7 to 3.9 represents the law and policy system within a System of Systems framework, but does not illustrate the institutions that implement and administer the law and policy. Because of the overlap between agencies and the interaction of multiple types of laws, the type of representation described for the previous figures would not accurately represent the different systems, their relations to one another, and the overlap between agencies in implementing the laws and policies. Using similar representation techniques developed for the CLIOS process, Figure 3.10 represents the conceptual framework for the interaction between the law and networked infrastructure. In contrast to the CLIOS representation, where the physical system is on "plates" embedded within an institutional sphere, Figure 3.10 shows each system as a "plate." The plates are stacked on top of one another, with law and policy as the top plate. Within the law plate, different types of law are illustrated. In this case, maritime law, environmental law, and labor law are represented by three different colors. While distinct areas of law, there is interaction between them, as illustrated through the overlap of the different circles. The next plate is the maritime law, which expands the maritime law circle, focusing on specific laws within the maritime law domain. Included in this domain is the Jones Act. Like the broad areas of law in plate one, statutes can cross multiple legal domains. The Third plate, the institutional system, focuses on those agencies that administer a particular statute, policy, or regulation. Finally, the fourth plate is the physical network, governed by the institutions, laws and policies that affect its operations.

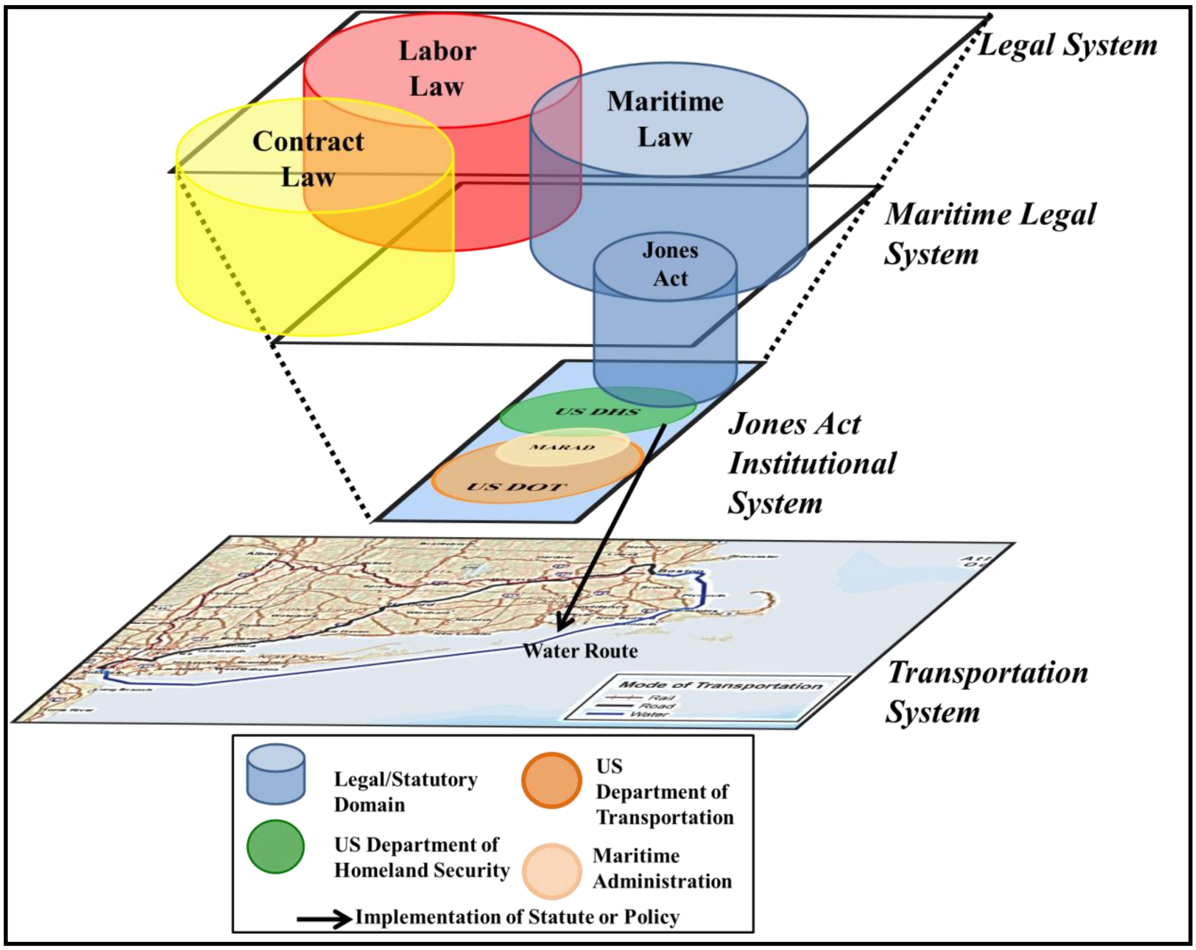

Figure 3.10: System of Systems framework for Analyzing the Jones Act
Credit: M. Fialkoff (2017) as modified from Mansouri et al. (2009)

3.6 Summary

This chapter provided a survey of the pertinent literatures involved in the analysis of how changing a law such as the Jones Act would affect the freight transportation network in the aftermath of a disruption. Working from multiple literatures, including critical infrastructure, law, resilience, and freight transportation planning, multiple systems interact when a change in one system affects another. Because of such complexity in multiple systems, this chapter also developed a conceptual framework to address shortcomings in the traditional systems view of transportation. Accounting for the interaction of multiple, interacting systems and the emergent behavior that can result from such interactions, the System of Systems framework provides a platform to study how a change in the legal system affects operations in the transportation system and vice versa. Insofar as this chapter provides the conceptual framework to carry out the proposed research, Chapter 4 discusses the hypotheses generated, data used, and methodology for studying the questions presented.

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Chapter 4: Research Design, Methods, and Datasets Used[1]

4.1 Introduction

Chapters 2 and 3 provided a context and framework to study the effect of law on networked infrastructure. Specifically, Chapter 2 introduced Hurricane Sandy, its impact on freight transportation networks, and the concern that the Jones Act restricted recovery in the aftermath. Although informative, the traditional systems view of transportation does not provide a sufficient foundation for studying the effect of a law such as the Jones Act on networked infrastructure, such as freight. Chapter 3 then introduced the System of Systems framework. This framework addresses the interaction of multiple, independent systems and acknowledges emergent behaviors, such as resilience, when these systems interact. Using this framework, Chapter 4 presents the research questions and hypotheses derived from the critiques of the Jones Act as a barrier to recovery in the freight transportation system.

Building off the discussion Chapter 2 on diversion analysis, this chapter develops the methodology used to study the effects of the Jones Act on the freight transportation network. The chapter explains the selection of WebTRAGIS as the platform used for the analysis, comparing it to other diversion analysis tools. Although Chapter 2 provides an in-depth discussion of the events surrounding Hurricane Sandy, this chapter explains how it is used as a case study, with a focus on the application of the Jones Act. The available data that makes the analysis possible will also be discussed. Chapter 4 also discusses important research design considerations and the development of scenarios used to evaluate changes related to the Jones Act.

Finally, the chapter concludes with discussion of the datasets used in this analysis. This research uses the Freight Analysis Framework (FAF) and the Confidential Carload Waybill Sample (CCWS). The differences between the data structure of the two datasets and the choice to use the CCWS over the FAF for the rail analysis is discussed. Attention is given to the two processes needed to use these datasets. The first examines the process for converting freight tonnages provided by FAF into trucks. The second provides the methodology used to measure rail traffic flows.

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[1] Portions of this dissertation chapter were used in the following publication:
Fialkoff, M.R.; Peterson, S.K.; Hancock, K.L. (under review). Putting the Spatial into Non-Spatial Data: Implementation of the Confidential Carload Waybill Sample for Routing Railroad Freight Flows. *Currently under review by the Journal of the Transportation Research Forum*.

4.2 Research Questions

In the aftermath of Hurricane Sandy, research by Southworth *et al.* (2014) and Flynn (2015) indicated a gap in understanding the impact of the Jones Act on freight transportation networks experiencing disruption. Flynn (2015) specifically recommended using Geographic Information Systems technology and High Performance Computing to develop models for studying the impacts of disruptive events on networked infrastructure. As recent as July 2016, TRB initiated NCFRP-50, with the overall goal of understanding freight transportation resilience using different methodologies. The overall goal of this study seeks to understand the institution, economic, and network effects of disruption to the freight network (Rogers, 2016).

To date, there is no research identified studying the effect of the Jones Act on freight transportation networks experiencing disruption. More generally, there is limited research on the interaction of law and infrastructure during a time of disruption. By using the System of Systems conceptual framework developed in Chapter 3, this research proposes the following research questions:

1. *What effect does the imposition and subsequent relaxation of the Jones Act have on freight transportation networks experiencing disruption?*
    a. *What effect does the imposition and relaxation of the Jones Act have on the movement of goods over highway networks experiencing disruption?*
    b. *What effect does the imposition and relaxation of the Jones Act have on the movement of goods over railway networks experiencing disruption?*
2. *How can existing transportation data assist in the study of policy-based interventions on transportation networks experiencing disruption?*
3. *What policy recommendations are available to reform the Jones Act and the current legal environment relating to short sea shipping in the United States in relation to disruptive events?*

4.3 Research Hypotheses

From the questions presented above, the following hypotheses are proposed:

- *Hypothesis 1: Relaxing the Jones Act under disruptive circumstances will mitigate traffic issues within the freight transportation network.*

- *Proposition 1a: Relaxing the Jones Act under disruptive circumstances will not significantly increase truck traffic flow over highway links emanating from marine freight.*
- *Proposition 1b: Relaxing the Jones Act under disruptive circumstances will not change traffic patterns on railways experiencing increased traffic demand.*

- *Hypothesis 2: Integrating, calibrating, and evaluating transportation and related data in a geospatially enabled analysis environment will provide a useful platform for studying policy interventions on transportation networks.*
- *Hypothesis 3: Reforming the Jones Act will encourage the use of short sea shipping as an alternative strategy for freight transportation during disruptive events.*

4.4 Models and Methods

Chapter 2 provided a brief introduction to freight diversion analysis. Diversion analysis focuses on the impact of a disruption on the freight transportation network (Southworth *et al.* 2014). Figure 4.1 reintroduces the concept of diversion analysis reflecting how such a diversion happened in Hurricane Sandy.

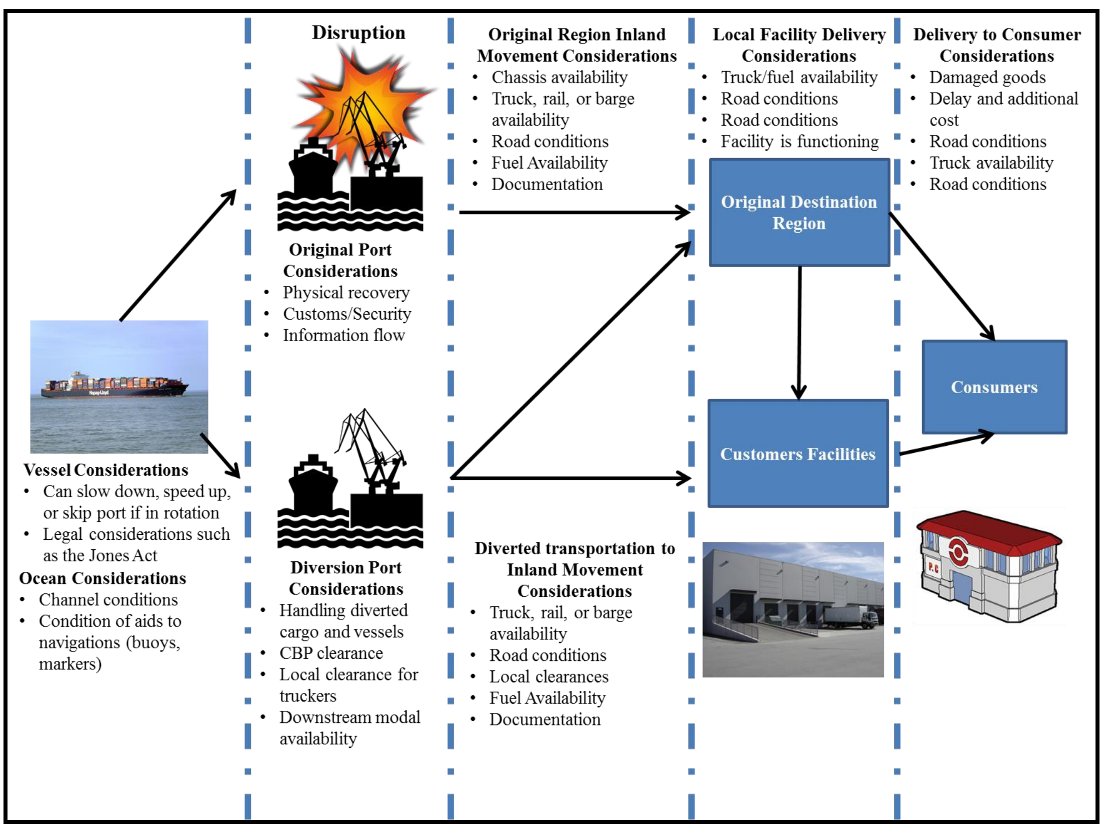

Figure 4.1: Import Container Diversion Flow
Source: Adapted from Southworth et al. (2014)

At each step of Figure 4.1, the disruption causes changes to operations and presents regulatory and legal challenges. For example, for trucks going to a diversion port to pick up diverted cargo, the trucks must have proper identification and tags to enter the port facility. In cases of disruption, this paperwork is not always available and slows down pick-up of freight. In addition to legal challenges, increased pressure on Customs and Board Protection (CBP) slows down their ability to clear trains to leave the port to move inland with diverted freight. Because the diversion port was not the intended destination, the bill of lading is incorrect, slowing down the processing time for clearing freight out of the port.

4.4.1 Models for Freight Transportation Diversion Analysis

Analyzing freight transportation disruptions and diversions using geospatially enabled technology provides both an analytical and visual platform to study these events. Over the past ten years, studies discussed below analyzed freight disruption and diversion. These studies assessed the impact of disruption on the freight network.

In the area of freight transportation research for network disruption, operation research has also been used to study the impact of disruption on networks. For example, Gedik *et al.* (2014) apply a mixed integer, bi-level program to study the effect of rail rerouting for coal trains when the train needs to be rerouted due to a disruption in the network. The advantage to this type of approach is that it is highly operationalized, meaning that operational characteristics such as number of cars per train, operating hours, number of plants, mines, and deliveries can be built into the problem in the form of constraints. On a system wide level, work by Miller-Hooks, Zhang, and Faturechi (2012) illustrated the overall resilience of a system based on a mixed-integer program that implemented various constraints to represent the operational characteristics for the different modes of interest. As Crainic and Laporte (1997) explained in their research, strategic and tactical research focused on regional planning provides the best level of analysis for understanding policy impacts in the area of transportation. Although the operations level research can inform specific decisions, its scope is narrow and cannot be generalized for planning or policy purposes.

Previous research using freight disruption and diversion analysis focused on modal specific diversions instead of the impact on the multimodal network. Most of the prior research analyzed disruptions to the highway or railway network. Early diversion research for railways used a Simple Routing Model (SRM) to study the diversion of trains in the event of a bridge collapse (Peterson ad Church, 2008). The SRM uses the classic shortest path solution, Dijkstra's algorithm, to determine an alternative path because of a bridge closure in Sandpoint, Idaho (Peterson and Church, 2008). For this work, Peterson and Church (2008) relied on the Railroad Routing Visualization Analysis module developed as an extension to the WebTRAGIS program.

Other railroad diversion research used different models, data sources, and methods to study disruption in the rail network. In contrast to focusing on the network impacts, other analysis focused on how commodity flows changed because of a disruption (Stich, 2014). In contrast to the previous study, the data needs for studying commodity disruption are greater. In addition to a change in data needs and the specificity needed for understanding commodity flow between points, the tool and network used differed from the work of Peterson and Church (2008). Stich's (2014) work used the Center for Transportation Analysis (CTA) multimodal network and the impedance formula developed for flowing commodities over the network. While both approaches lend themselves to understanding the effect of the disruption for either the network or particular commodities, there are drawbacks. Stich's work recognized challenges, especially in the data needs for studying commodity flow at a highly resolved level of analysis. The model used by Stich (2014) provided less information on how the model generated routes, and assumed the parameters associated with the CTA network and its routing engine.

Aside from rail, truck disruption and diversion research uses different techniques to study how truck flow changes because of disruption. In 2012, two studies presented different approaches to the problem of disruption on the highway network. The first developed a risk-based approach to identify critical links in the Tennessee highway network and developed an approach for preferred alternative routing (Kersh, Dobbins, and Abkowitz, 2012). Using a dataset provided by the Tennessee Department of Transportation (TDOT), potential crash hot spots and preferred alternative routes were identified (Kersh, Dobbins, and Abkowitz, 2012). In contrast to rail studies that struggle to calculate rail capacity Kersh, Dobbins, and Abkowitz (2012) used traffic density and Level of Service (LOS) as measures of whether the alternative routes were feasible in the event of a road closure.

Whereas the previous studies described used datasets and GIS to analyze predictive routes, the use of Global Positioning System (GPS) technology provides planners with real-time information for studying diversion impacts. The second report published in 2012 used GPS technology to study available alternative routes resulting from flooding around I-40 in Arkansas during May 2011 (Pierce and Short, 2011). In contrast to predictive analysis, using GPS provides a more concrete understanding of diversions and relies less on modeling and more on real-time decision making by drivers who have to make quick decisions on changing their route. Whether using predictive analysis or real-time information, the challenge associated with diversion analysis is ensuring there is enough data to conduct the analysis.

In 2012, the National Cooperative Highway Research Program (NCHRP) published Report 732, *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System* (Georgia Tech Research Corporation *et al.* 2012). NCHRP 732 began the process of categorizing various approaches to understanding goods disruptions and condensed the research into two broad categories, network-based models and supply chain response models. In the network-based models, the category is further decomposed into simple cargo diversion models that use a shortest path or least cost path algorithm and more complex freight network simulations. From the perspective of the network-based models, the economic factors associated with commodities were largely assumed. The emphasis for the network models was the impact on the transportation infrastructures involved in the diversion. In NCHRP 732, various network models were identified that could be used to study diversion effects. Such models included the Disruption Impact Estimating Tool-Transportation (DIETT) model and the Transportation Routing Analysis GIS (TRAGIS). With DIETT, the interface was primarily Microsoft Excel and Access driven, whereas TRAGIS relies on GIS based technologies.

While TRAGIS has not been used extensively for freight diversion work, Fialkoff *et al.* (2017) explored the applicability of TRAGIS for freight diversion during Hurricane Sandy. The work offers an initial parameterization of the freight diversion that occurred in the aftermath of the storm. In particular, the authors modeled various scenarios for the ports affected by the storm and visualized highway, railway, and waterway routes for freight to return to the New York metropolitan area. In contrast to the work undertaken in this dissertation, Fialkoff *et al.* (2017) used multiple ports and only highlighted potential routes. For this dissertation, the focus is on the Port of Norfolk and does not assume New York as the destination. Within the work by Fialkoff *et al.* (2017), the routes were limited in the respect that they only reviewed the routes and not the freight flowing over the routes generated by TRAGIS, similar to the results published by Peterson and Church (2008).

4.4.2 Selection of TRAGIS for Diversion Analysis

For this research, TRAGIS was used to generate routes and flow the Freight Analysis Framework and the Confidential Carload Waybill Sample data over the respective networks. In *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System*, both DIETT and TRAGIS were acceptable tools for conducting freight diversion research as both represent network-simulation based approaches to understanding freight disruptions. DIETT is a disruption impact tool that relies on Microsoft Excel and Microsoft Access to feed data for the subsequent analysis. Although the user interface for TRAGIS does not allow for the flowing of freight data like DIETT, the batch process associated with TRAGIS allows the user to generate multiple routes with freight flow associated with each route.

With DIETT, there is the possibility for linkage to GIS, but this requires subsequent Access or Excel tables that contain network information. From these tables, the network could be read by DIETT and then exported to GIS programs for visualization. In contrast, TRAGIS is a GIS based routing tool that allows the user to input the mode of choice, the origin, the destination, and if appropriate, the rail carrier. In contrast to DIETT that analyzes highway disruption, TRAGIS is a multimodal tool that generates routes for road, rail, and water transportation.

Although *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System* did not recognize the ORNL CTA networks as a disruption analysis platform, the fact that Stich (2014) used them in her research requires a brief discussion of why TRAGIS was used over the CTA networks. Even before reaching the differences in network and data structure between the networks used for TRAGIS and those used in CTA, a major driver for using TRAGIS was the fact that TRAGIS has an easy to use Graphical User Interface (GUI). One of the challenges with using the CTA networks is lack of a user-friendly interface that can allow researchers to enter parameters and other inputs (Stich, 2014). With TRAGIS, a GUI allows for parameterization of routes. The CTA networks were only for analytical research, not visualization. Their visualization through GIS was never an initial consideration, rather a back-end necessity for reporting results.

When comparing the network data structure of the CTA network and the networks used in TRAGIS, there are certain assumptions built into the network based on accepted practices about freight transportation. These accepted practices relate to the transfer time between modes, the construction of virtual networks to link different modes, and brute force implementation so the network operates based on these accepted principles. The problem with this approach is that the user relies on the CTA network's assumptions with limited documentation to support the assumptions made. Again, the CTA network's primary use was to analyze freight flow, not visualize it. In contrast to TRAGIS, the CTA networks provide an intermodal capability for freight to move between multiple modes for a given route. While TRAGIS has the code for intermodal routing, to date, it has not been implemented.

Ultimately, TRAGIS was selected over DIETT and the CTA networks for the following reasons. First, TRAGIS has supporting documentation that clearly explains the routing algorithm, a procedure for route generation, and the ability to batch process multiple routes making the tool appealing given the number of routes needed for both the highway and railway data. Second, while the CTA provides both multimodal and intermodal capability, the use of virtual links and key assumptions in the transfer of freight from one mode to another mode is problematic. There is limited documentation explaining the values used. This creates problems for validation. Finally, both Georgia Tech Research Corporation *et al.* (2012) and the work by Fialkoff *et al.* (2017) have illustrated that TRAGIS tool is a viable tool for studying the policy-based questions that emerge from transportation disruptions. Table 4.1 illustrates the various factors considered when evaluating the CTA networks, DIETT, and TRAGIS.

Table 4.1: Characteristics/Strengths of Available Tools for Diversion Analysis

	CTA Networks	**DIETT**	**TRAGIS**
Batch Processing			✓
Data Fusion	✓	✓	
Disruption Impact Performance Measure		✓	
Ability to flow freight	✓		✓
GIS Visualization	✓		✓
Graphical User Interface		✓	✓
Intermodal Routing	✓		
Multimodal Network	✓		✓
Prior use in Disruption Research	✓	✓	✓
Route Generation	✓		✓
Supporting Documentation		✓	✓

Credit: M. Fialkoff (2017)

4.5 Research Design and Conceptual Framework

Given the research questions presented in Section 4.2, this study developed three scenarios to test the impact of the Jones Act on freight transportation networks experiencing disruption. The three scenarios are:

- Scenario 1: normal operating conditions for freight transportation,
- Scenario 2: freight conditions during Hurricane Sandy with the Jones Act kept in place, and
- Scenario 3: freight conditions during Hurricane Sandy with the Jones Act relaxed.

This treatment of a policy intervention as testing the effect of the intervention in place and its removal can be compared with the with/without approach as described by Creswell (2012). In the with/without approach, a situation is observed with the law or policy in place (with) and then observed with the policy intervention removed (without).

This research used work by Flynn (2015) and Southworth *et al.* (2014) to develop a picture of the amount of freight diverted from New York to Norfolk and other facts about the impact of Hurricane Sandy on the freight network. In addition to these studies, port operators, barge operators, Norfolk Southern, and CSX Transportation affected by Hurricane Sandy provided baseline information as to the freight flows emanating from the Norfolk International Terminal (NIT) because of the diversion. From these discussions, the parameterization of freight flows allowed for a complete understanding of how freight was moving because of the diversion from New York to Norfolk.

The System of Systems framework developed in Chapter 3 provides the framework for studying how a law, such as the Jones Act affects the networked infrastructure it governs. In contrast to Systems Thinking, the law component is neither well defined nor developed as it relates to its impact on technical domains such as transportation. In contrast, the System of Systems (SoS) framework recognizes that law is a separate system that exhibits managerial and operational independence described by Maier (1998). Borrowing from Luhmann's (1991) discussion of legal systems as separate, the Legal System in Figure 4.2 represents various legal sub-systems, including maritime, environmental, and labor law. The second and third plate illustrates the maritime law sub-system, and its subsequent administration and implementation. The bottom plate represents the physical network. Recognizing the importance of legal and institutional systems within the System of Systems literature, the framework developed for this research is presented in Figure 4.2. Using similar visualization techniques to CLIOS, each "plate" represents a system, separate and apart from the other systems represented.

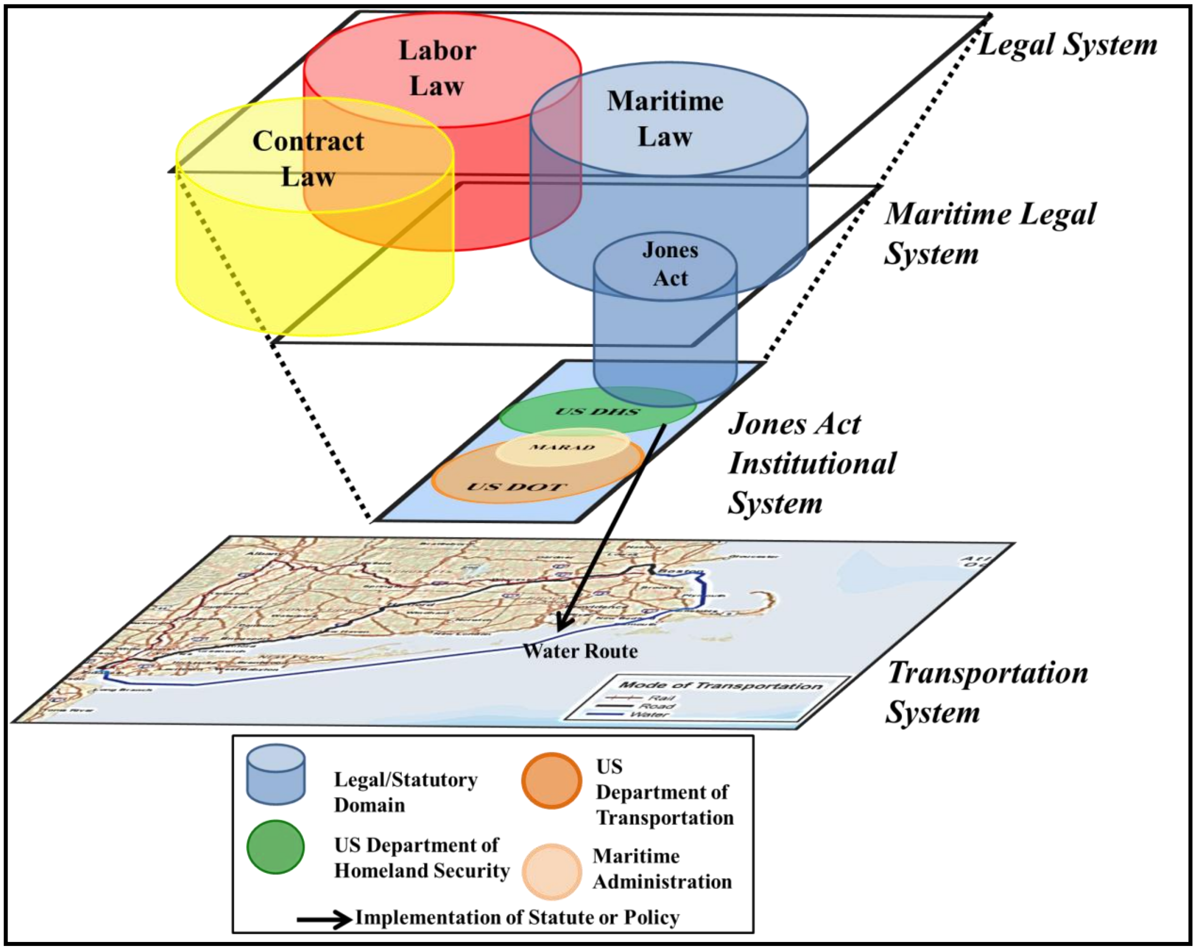

Figure 4.2: System of Systems framework for Dissertation
Credit: M. Fialkoff (2017)

While the diversion analysis will answer research questions 1 and 2, research question 3 uses traditional legal analysis to study the Jones Act, with a particular focus on the cases relating to the Jones Act waiver process. With the recent decision in *Furie Operating Alaska LLC. v. U.S. Department of Homeland Security,* the Jones Act waiver process has been determined to be unreviewable by Article III courts and committed to agency action. The research associated with this question will interrogate administrative remedies and statutory reformation as pathways for allowing a more flexible waiver process.

4.5.1 Selection of Hurricane Sandy as the Case

Chapter 3 summarized the effect of Hurricane Sandy on the freight transportation network. Hurricane Sandy is not the first time the Jones Act has been an area of interest for the maritime transportation community. Following the events of Hurricane Katrina, President Bush gave a complete waiver of the Jones Act (Hodgson and Brooks, 2007). With a total suspension of the Jones Act, international vessels were able to engage in coastwise trade given the devastation along the Gulf Coast. If Hurricane Sandy is not the first time the Jones Act was suspended or kept in place, why is Hurricane Sandy used in this dissertation to study the effect of the Jones Act on transportation networks experiencing disruption?

After Hurricane Sandy, the Jones Act remained in place in the immediate aftermath of the storm, but was subsequently relaxed for petroleum products so that the New York metropolitan area could receive heating oil. In contrast to Hurricane Katrina where a blanket suspension was given, the suspension given in Sandy was part of the Statute, which allowed a waiver only in the interest of national defense and security. Within that interpretation, it was determined that movement of petroleum products was in the national interest, but movement of containerized cargo, bulk goods, and other dry cargoes were not of equal importance.

Subsequent reports on the response and aftermath of Hurricane Sandy focused on the role of the Jones Act as a barrier to recovery for the freight transportation networks. In Southworth *et al.* (2014), the Jones Act was cited as a barrier to modal flexing, the ability of other modes to pick up the slack when one mode becomes disabled (Southworth *et al.* 2014). The restriction on short sea shipping isolated the Port of New York and New Jersey from the rest of the transportation network, but also had impact on the Port of Norfolk. Because Norfolk was receiving an increased traffic load from diverted traffic and the Jones Act was still in place, traffic was passed onto downstream modes, primarily railroads and trucks. Approximately 6,500 containers that were bound for New York ended up in Norfolk (Flynn, 2015). Of those 6,500 containers, 2,100 containers were transported by barge from Norfolk to New York (Villa, 2016). This left 4,400 containers transported by rail and road haulage.

With respect to diverted cargo, Hurricane Sandy presents a case where the diverted container volumes have been reported in the news and literature. Approximately 6,500 containers were diverted to Norfolk and another 8,500 containers were diverted to the Port of Halifax (Flynn, 2015). Both the 6,500 container and 8,500 container values were confirmed by communication with the Port of Halifax[2] (McInnes, 2016; Lombardi, 2014; Cresenzo, 2012). Given the comprehensive understanding the diverted freight flow, this affords the opportunity to load the network with an estimate of the number of containers that were diverted to Norfolk.

[2] According to Robert McInnes, Manager for Business Development at the Port of Halifax, approximately 8,000 TEUs were handled by the Port of Halifax as a result of the diversion. As TEU is a unit for containerized cargo, it is unclear whether this was 8,000 1 TEU containers or 4000 2 TEU containers (McInnes, 2016)

4.5.2 Scenario Development

To study the impact of the Jones Act on the freight transportation movements during Hurricane Sandy, three scenarios were developed that reflect the Jones Act as a policy intervention. Within each of the three scenarios, all conditions are held constant so that the only variable is the waiver of the Statute. This section describes each of the scenarios.

- **Scenario 1: Baseline Freight Movement-Normal Operations**

Scenario 1 represents "normal" freight operations and acts as a control scenario. In this scenario, freight will flow according to the data as represented in the Freight Analysis Framework and the Confidential Carload Waybill Sample. In this scenario, the Jones Act is in place with no additional freight moving out of Norfolk. Because Hurricane Sandy increased traffic loads exiting from Norfolk, this scenario also represents a "before" frame of reference for freight movement. This scenario acts as a baseline comparison for the other two scenarios that have increased freight loading on both the rail and highway networks.

- **Scenario 2: Hurricane Sandy Conditions- Jones Act in Place**

Scenario 2 approximates how freight moved in the aftermath of Hurricane Sandy, with the Jones Act in place. This scenario represents additional network loading of the rail and road networks of 4,400 containers. Although Flynn (2015) reported that 6,500 made land-fall at the Norfolk International Terminal because of the Port of New York and New Jersey suspending operations, Columbia Coastal barge company has acknowledged that 2,100 of the 6,500 containers were moved via barge back to the New York metropolitan area (Villa, 2016).

This leaves 4,400 containers to be loaded onto the rail and road networks leaving Norfolk. As described by the Port of Norfolk website, the mode split for freight leaving Norfolk is estimated to be the following: 64% leaving the facility by road, 33% leaving by rail, 3%, leaving by water/barge (The Port of Virginia, 2017).[3] When loading the network, the original mode split values were multiplied across the 4,400 containers to obtain the increased container load by mode. For Scenario 2, this represents an additional 2,816 containers moving by road out of Norfolk and an additional 1,584 containers moving by rail out of Norfolk. Within this scenario, barges move 2,100 containers. The containers are then loaded onto the network

[3] At the time of the writing of this dissertation, the mode split for the Port of Virginia has changed slightly with the new mode split as follows: Truck-60.6%; Rail-36.7%; Water- 2.7%. The values reported above are the values used to allocate additional freight loading, though values represented in this footnote represent the mode split as of January 28, 2017

according to individual percentage of origin-destination traffic leaving from Norfolk. An example of this dispersion is illustrated in Figure 4.4

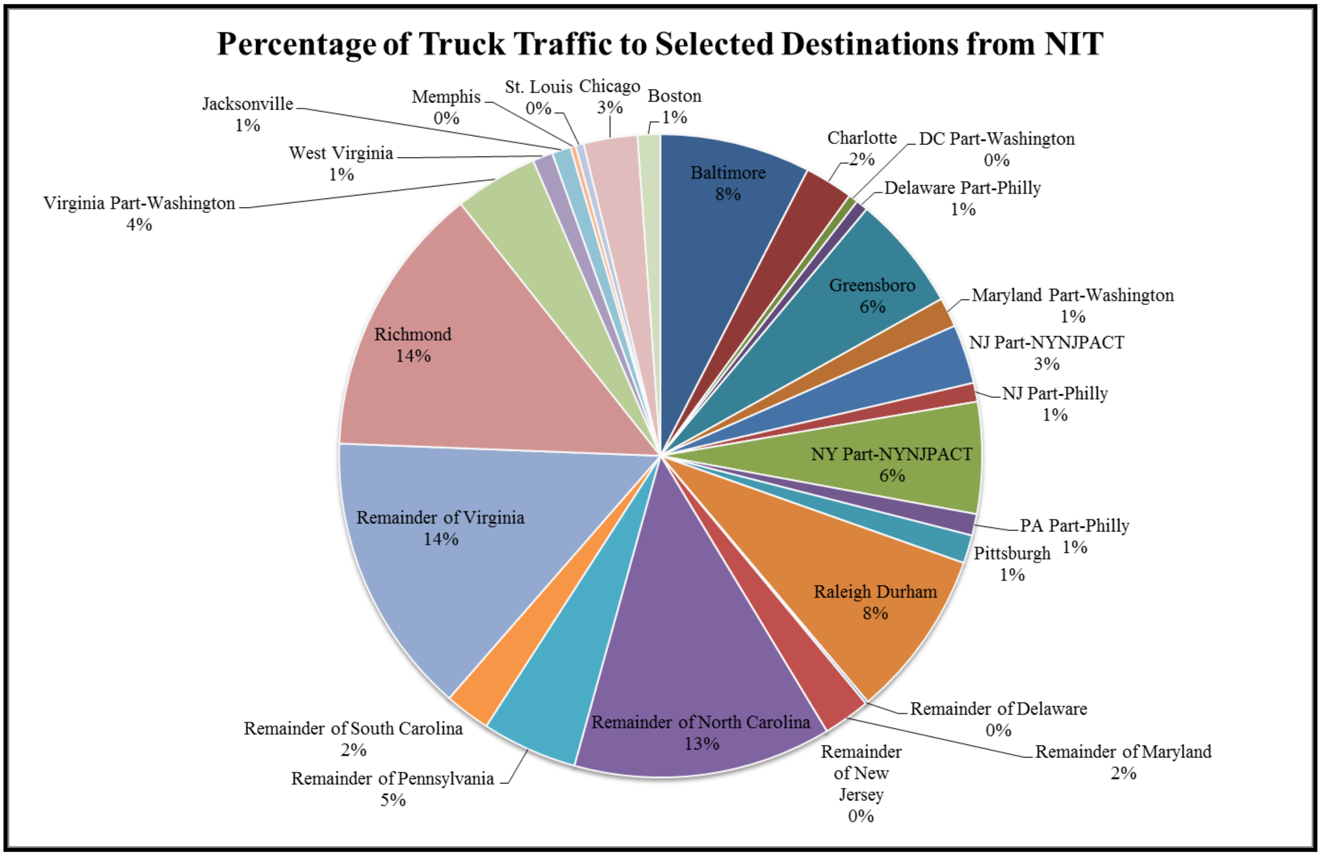

Figure 4.2: Truck Traffic from NIT to Selected Destinations
Credit: M. Fialkoff (2017)

- **Scenario 3: Hurricane Sandy Conditions- Jones Act Relaxed**

Scenario 3 approximates how freight moved in the aftermath of Hurricane Sandy, without the Jones Act in place. Similar to Scenario 2, this scenario represents additional network loading of the rail and road networks of 4,400 containers. In contrast to the previous scenario, all three modal options leaving from Norfolk are loaded equally with diverted freight. In this scenario the mode split is ignored as reported by the Port of Norfolk because this mode split is based on no short sea shipping. In this scenario, all three modes have equal access and at equal parity for use by customers wanting to receive their diverted cargo. Because no demand schedule is in place with limited information on the willingness of customers to pay for short sea shipping, freight customers have three equal choices for choosing transportation out of Norfolk in the case that their freight is diverted. With 6,500 distributed across the three modes, each mode will receive an additional load of approximately 2,166 or 2,167 (the road and water modes received 2,167 containers and the rail mode received an additional 2,166 containers). Table 4.2 summarizes the additional loading for the three scenarios.

Table 4.2: Additional Container Loading for Scenarios

	Scenario 1	**Scenario 2**	**Scenario 3**
Truck	4160	2816	2167
Train	2145	1584	2166
Barge/Vessel	195	2100	2167

Credit: M. Fialkoff (2017)

4.6 Datasets Used

For this dissertation, two transportation datasets are used to flow freight over the routes generated by TRAGIS. The Freight Analysis Framework (FAF) and the Confidential Carload Waybill Sample (CCWS). Although the FAF records freight flow for multiple modes including railroads and waterways, the CCWS contains more complete rail data.

4.6.1 The Freight Analysis Framework (FAF)

The United States DOT's Freight Analysis Framework (FAF) is an extensive freight database of goods moving through the United States (Southworth, 2011). The database is an amalgamation of supporting databases that include the U.S. Commodity Flow Survey (CFS), rail carrier information, inland barge traffic, air freight, pipeline flows, and deep-sea water freight transit data. The data is structured by the CTA at ORNL and is supported and distributed by the Federal Highway Administration (FHWA) within U.S. DOT. The FAF measures domestic and foreign freight flows moving into and through the United States across seven modes of transportation.

The data architecture for the FAF takes all the data sources described above and creates matrices for commodity flow between zones within the United States and foreign zones. The first step in this data construction is the development of the base year freight flow. The FAF is currently in its fourth iteration, with FAF4 using 2012 as its baseline year. For this dissertation, FAF4 was used and the 2012 base year was used for data extraction. In addition to providing baseline freight information, the FAF is able to project freight flows using a technique known as the Iterative Proportional Fitting (IPF) routine, which can fill in the holes with the multi-million cell freight matrix for commodities across multiple years. Using the national flow model and IPF, multiple commodity types can be projected across multiple years.

The commodity movements are based on zone-to-zone movements, with the United States divided into three types of zones. The first zone represents states with low populations or small states that unto themselves represent zones. Examples of these state zones include Vermont, Montana, Idaho, Iowa, and New Mexico. The second type of zone is metropolitan regions. These metropolitan zones can cross states and represent major population and production areas. Such zones include Philadelphia, Norfolk, Los Angeles, New York, Atlanta, and Charleston. The third and final type of zone is what is described as State Remainders. For states where there are metropolitan zones, the areas with small populations that do not form metropolitan regions are deemed to be "State Remainders." These remainders can cut across states depending on the geography of the metropolitan zone within the state. Figure 4.5 illustrates the FAF zone types and their distribution across the continental United States. The FAF also accounts for imports brought in from International Zones. For this research, those international zones are not part of the analysis.

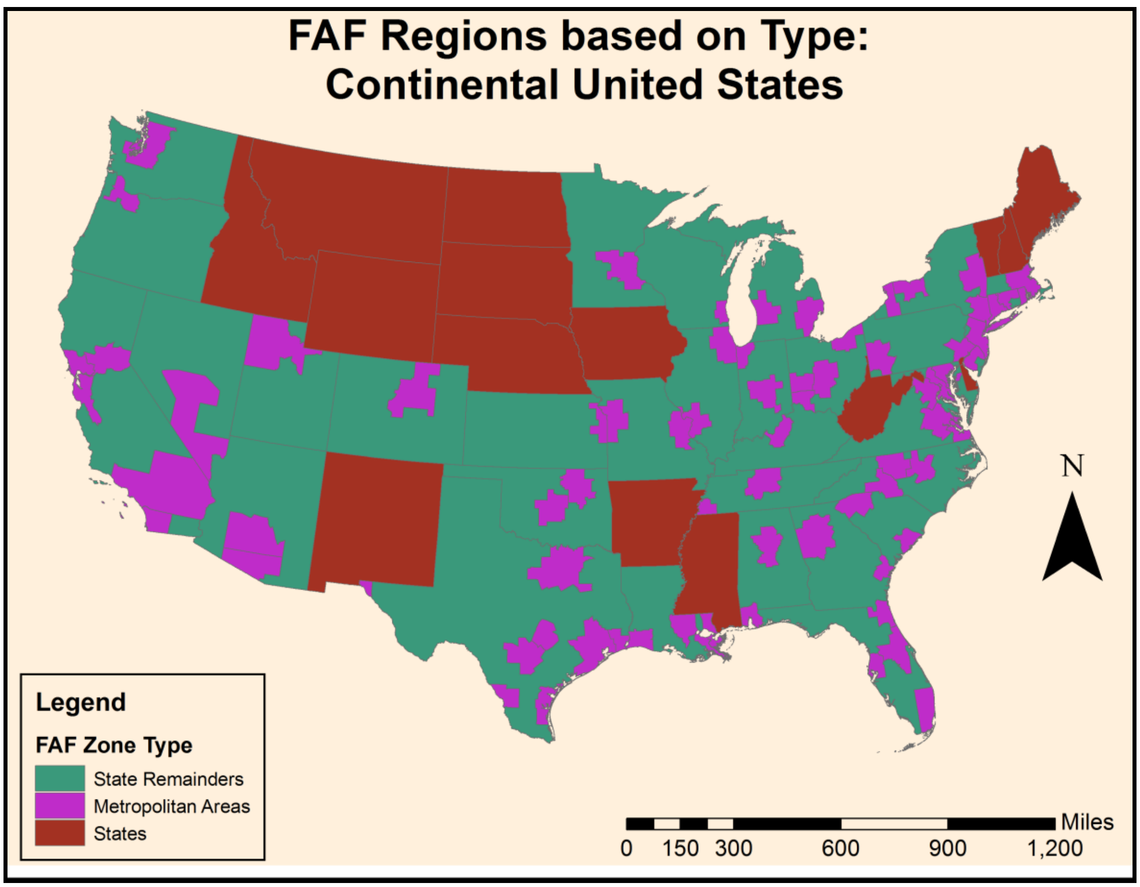

Figure 4.3: FAF Regions for Continental United States
Data Source: Federal Highway Administration FAF Zones Shapefile. Available at:
https://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf3/netwkdbflow/

Although the FAF is the best representation of national freight flow for the United States, it suffers from a problem of data disaggregation. As Figure 4.3 illustrates, the zones are large metropolitan areas, remainders of states with metropolitan zones, or in some cases, whole states. As Bujanda, Villa, and Wilson (2014) acknowledged, "[although] FAF3 provides reasonable estimates for national and multi-state corridor analyses, FAF3 estimates do not have the sufficient level of disaggregation to support local, regional, or state planning and project development" (p. 48). Individual states have tried to disaggregate the FAF data for their individual state for more nuanced freight flow movement within state (Mitra and Tolliver, 2012 and Rowinski, Opie, and Spasovic, 2008), though there is no national disaggregation strategy for interoperability across state lines. In the context of the railway, this disaggregation issue becomes even more evident, with the CCWS providing more detailed information for locating origins, destinations, and interchanges.

4.6.1.1 Converting FAF Tonnages to Trucks

The data structure of the Freight Analysis Framework breaks out zone-to-zone trips based on individual commodities. The FAF does not estimate Average Daily Truck Trips (ADTT) (Battelle 2011). To convert commodity to payload for trucks, an assignment process is needed that takes into account a variety of factors, including the distance between zones, the commodity being moved, truck allocation, truck equivalency factors, and empty truck factors. For the last three factors, the process uses the 2002 Vehicle Inventory and Use Survey Database (VIUS) (Battelle 2011). The VIUS provides a national and statewide inventory of total number of trucks used and what type of truck is used for each commodity. Although dated, this is the most recent survey of vehicle inventory and use. The protocol described uses Battelle's (2011) methodology and the resulting lookup tables derived from the 2002 VIUS survey. The workflow for conversion of zone-to- zone commodity movements from the FAF and subsequent integration into WebTRAGIS is shown in Figure 4.4.

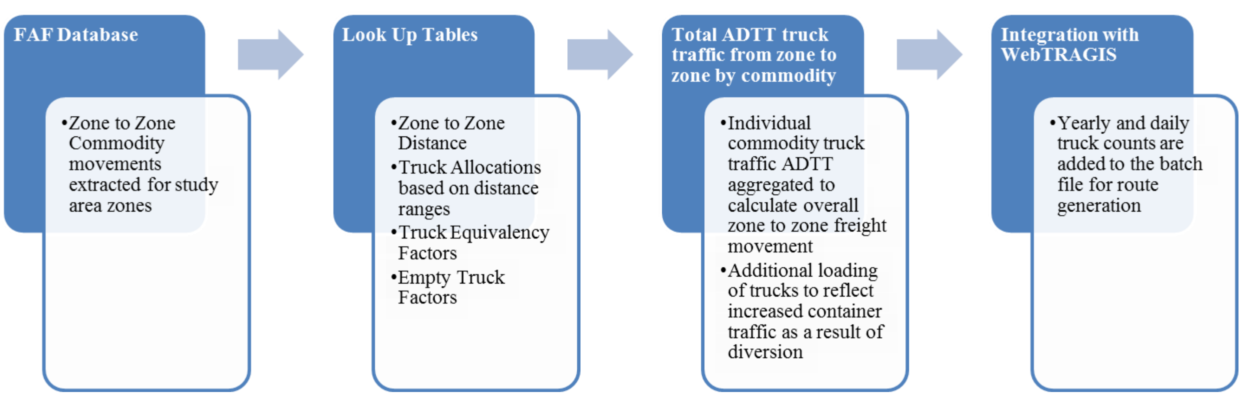

Figure 4.4: Truck Conversion workflow
Source: Adapted from Battelle (2011)

The first step in the process is to extract the necessary commodity information for the study area zones from the FAF. To acquire the necessary data, a series of filters were used within the FAF database to extract the necessary commodity data between zones. This process is represented in Figure 4.5, with the final number of records used being 64,711.

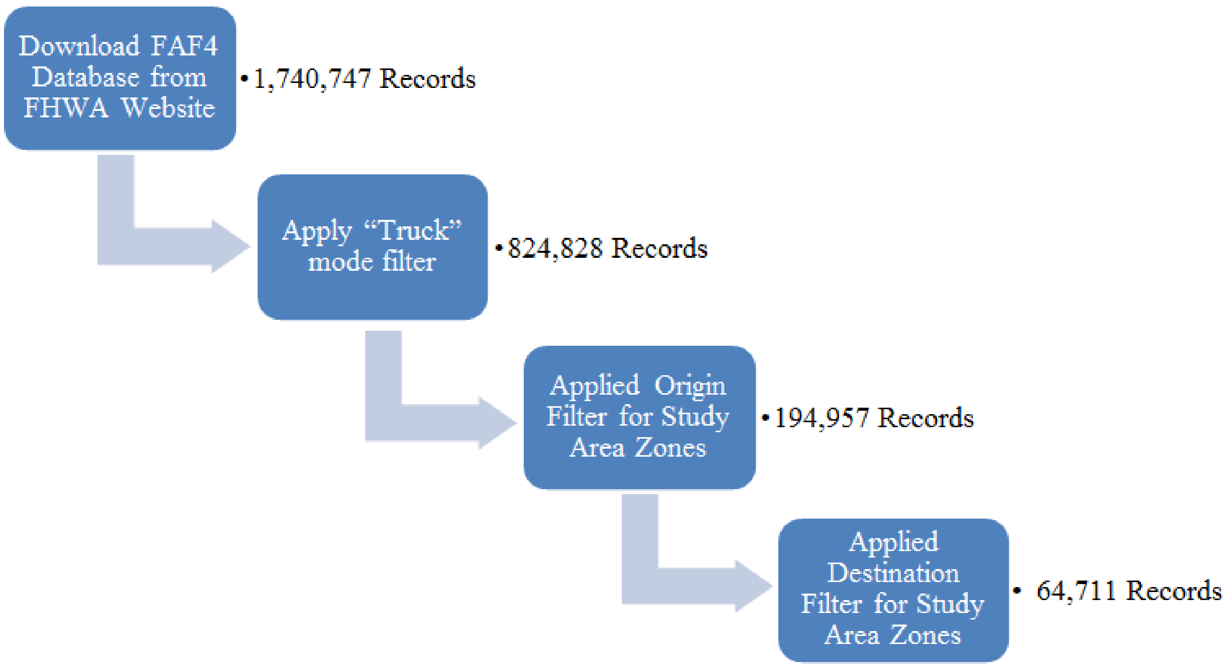

Figure 4.5: FAF Study Area Data Extraction Workflow
Credit: M. Fialkoff (2017)

For each zone-to-zone commodity movement, basic information is needed (the Origin Zone, the Destination Zone, the Commodity being moved, the Tonnage, the Value, and the Distance between Zones). An example will be used to explain the process illustrated in Table 4.3.

Table 4.3: Parameterization of Commodity to Payload Conversion

Origin	Norfolk
Destination	Baltimore
Commodity	1-Live Fish/Animals
Tonnage	561.5 Tons
Distance[4]	240 miles

Source: Battelle (2011)

The next few steps take the information from Table 4.3 and use a series of lookup tables to determine the truck allocation based on the distance value. Using a distance table that allocates

[4] For the distance value, a distance matrix was constructed with the twenty-three interior centroids and the five exterior centroids. This distance matrix formed a subsequent lookup table for the FAF payload calculations.

the commodity across the five truck types, Single Unit (SU), Truck Trailer (TT), Combination Semitrailer (CS), Combination Double (CD), and Combination Triple (CT), the tonnage is broken out according to which truck will be used given the distance between the zones. This is reflected in Table 4.4.

Table 4.4: Tonnage Allocation to the Five Truck Types

Truck Type	Allocation Factors[5]	Value	Unit
Single Unit (SU)	0.142467	79.995	Tons
Truck Trailer (TT)	0.027288	15.322	Tons
Combination Semitrailer (CS)	0.751628	422.039	Tons
Combination Double (CD)	0.075218	42.234	Tons
Combination Triple (CT)	0.002031	1.140	Tons

Credit: M. Fialkoff (2017)

After tonnages are allocated among the five truck types, the tonnage values in Table 4.4 are allocated across nine body types, using a truck equivalency factor lookup table. This value represents the loaded truck across the nine body types annually as shown in Table 4.5.

Table 4.5: Annual Truck Traffic, Loaded Trucks

	Single Unit	Truck Trailer	Combination Semitrailer	Combination Double	Combination Triple
Dry Van	0.34	0.28	0.26	0	0
Flatbed	3.94	1.50	2.65	0	0
Bulk	0.0066	0.036	0.37	0	0
Reefer	0.14	0	0.26	0	0
Tank	0.88	0	0.19	0	0
Logging	0	0	0	0	0
Livestock	0	0	11.12	1.25	0
Automobile	0	0	0	0	0
Other	0	0.047	0	0	0

Credit: M. Fialkoff (2017)

Table 4.5 only represents the amount of commodity-laden trucks. There are a proportion of trucks that are empty within traffic and accounted for using an empty truck factor. The values in Table 4.5 are adjusted using the empty truck factor. Using VIUS, approximately 50% of loaded trucks are not fully loaded and therefore the empty truck values are reduced by another 50% to reflect empty loading factors across the nine body types. As a point of reference, on the empty truck factor table, there are two cases, representing two different values, Domestic Shipping and

[5] The allocation factors table and all lookup tables referenced can be found in the FAF3 Freight Traffic Analysis Report by Battelle (2011).

Land Border Shipping. For this research, the Domestic values were used as the study area was domestic traffic. Continuing with the example, Table 4.6 reflects the consolidated values for loaded and empty trucks.

Table 4.6: Annual Truck Traffic, Loaded + Empty Trucks

	Single Unit	Truck Trailer	Combination Semitrailer	Combination Double	Combination Triple
Dry Van	0.34	0.28	0.30	0	0
Flatbed	3.90	1.50	3.18	0	0
Bulk	0.0080	0.041	0.444	0	0
Reefer	0.16	0	0.30	0	0
Tank	1.03	0	0.23	0	0
Logging	0	0	0	0	0
Livestock	0	0	12.12	1.41	0
Automobile	0	0	0	0	0
Other	0	0.50	0	0	0

Credit: M. Fialkoff (2017)

Next, the values for each of the five truck types are added together, generating annual truck traffic, which is reflect in Table 4.7.

Table 4.7: Annual Truck Traffic by Type

Truck Type	Annual Traffic	Unit
Single Unit	6	Trucks
Truck Trailer	3	Trucks
Combination Semitrailer	17	Trucks
Combination Double	2	Trucks
Combination Triple	0	Trucks

Credit: M. Fialkoff (2017)

The final step is adding together the values in Table 4.6 to determine the annual truck traffic for that particular commodity as represented in Table 4.7. To get the daily truck traffic for the commodity, the summed value is divided by 365. This process is repeated for the forty-three different commodities for each zone and is done for each zone-to-zone movement. To accelerate this process, a series of lookup tables and distance matrices were used. Once all the commodities were calculated for the zone-to-zone movement, an annual truck table was generated and then converted into a daily truck traffic table.

4.6.2 The Confidential Carload Waybill Sample (CCWS)

In the previous section, the FAF was introduced as the primary dataset that captures national freight flow for the United States. As previously pointed out, one of the challenges with the FAF is the disaggregation problem. Because of this high-level view of the freight data, the FAF lacks a county or point location for determining freight flow. In the case of railway freight flow, the added detail of which rail carrier is hauling the freight and the interchange location of where freight transfers between rail companies occurs, makes the use of the FAF for the rail portion of this dissertation problematic.

This dissertation uses the Confidential Carload Waybill Sample (CCWS) because of the more detailed nature of the CCWS in comparison to rail data in the FAF. The CCWS is a stratified sample representing 1 – 3% of all the waybill traffic moved by rail carriers maintained by the Surface Transportation Board (STB) (Waybills, n.d.). The CCWS dates back to the 1800s when the Interstate Commerce Commission (ICC) (now the Surface Transportation Board (STB)) used the waybills to study freight movements and was the primary source of data used in ICC proceedings. In recent years, the CCWS has been used for a variety of purposes including judicial and regulatory evidence to administrative bodies, market research and analysis, and modeling of freight flows for the railroad industry (RAILINC, 2014). It should be acknowledged at the outset that the data within the CCWS is a sample and those results reported from the CCWS are based off sample data and not the complete population of waybills that may exist for any given year. In contrast, the data in the FAF comes from models built from sample data.

In contrast to the FAF, the CCWS data structure is individual waybill records and not zone-to-zone movements. Within each record, the waybill reports routing information, rail carrier information, the commodity being moved, the type of equipment used to move the freight, and economic and revenue related to the individual carrier rates and shipping fees. This last piece of data, the economic and revenue information is heavily regulated by the STB. Although the STB "masks" the economic and rate data, the rail companies and the STB want to ensure these values are not published to preserve the rail company's proprietary rate schedules. "Because the Waybill Sample contains sensitive shipping and revenue information, access to this information is restricted" (Waybills, n.d.). While Federal Agencies and other users have access to the CCWS, general use for research requires obtaining permission from the STB. To obtain access to use the CCWS, the user needs to demonstrate that collecting the information another way would be either costly or highly burdensome to the requester. Release of the waybill requires that prior to publication of any report, article, or dissertation, the STB review pertinent sections of a publication to ensure proper precautions and aggregation of data were undertaken. The rules for release of waybill data are codified at 49 CFR § 1244.9.

For this dissertation, the author received permission from the STB to use the CCWS for the years 2011, 2012, and 2013 in March of 2016. All documentation relating to use of the CCWS is on file with the STB Board and in Appendix C of this dissertation.

4.6.1.1 Rail Traffic by Volume and Capacity Analysis

Rail capacity analysis is a complex endeavor, as it requires operational knowledge of individual rail companies, inter-rail agreements, and geographic information across multiple sub-divisions within rail carriers and across rail companies. This section discusses some of the challenges associated with rail capacity analysis and outlines the approach used to study rail traffic volumes from the waybill sample.

Capacity can be defined as a measure of the ability to move a specific amount of traffic over a defined rail line with a defined set of resources (Krueger, 1999). Abril *et al*. (2007) elaborated on this definition by providing four types of capacity for railroads as shown in Table 4.8.

Table 4.8: Description of Rail Capacity Type.

Capacity Type	Description
Theoretical Capacity	• The number of trains that could run over a route, during a specific time interval, in a strictly perfect, mathematically generated environment, with the trains running permanently and ideally at minimum headway • It is an upper limit for line capacity • Assumes that traffic is homogeneous and trains are evenly spaced throughout the day with no disruptions. • Ignores the effects of variations in traffic and operations
Practical Capacity	• Practical limit of ‘‘representative’’ traffic volume that can be moved on a line at a reasonable level of reliability which are related to the level of expected operating quality and system reliability • The capacity that can permanently be provided under normal operating conditions • Approximately 60–75% of the theoretical capacity
Used Capacity	• Actual traffic volume occurring over the network • Lower than practical capacity
Available Capacity	• Difference between the Used Capacity and the Practical Capacity • It is an indication of the additional traffic volume that could be handled

Source Adapted from Abril et al. (2007)

In trying to parameterize capacity, Abril *et al.* (2007) list a number of factors that are considered for calculating capacity. These factors include infrastructure, traffic, and operating considerations. Of particular interest for this research is the infrastructure parameters, namely the blocking or signal system, the speed allowance on the given line segment, and the geographic interaction with the infrastructure (the track slope or grade).

Prior to Abril *et al.* (2007) and his survey on rail capacity, work by Clarke (1995) developed a formula to capture the capacity for a rail segment as represented in Equation 4-1:

$$D = t_a\left(K_1 V + K_2\left(V / C^{\gamma}\right)\right) \tag{4-1}$$

where

D = Average delay (trains/hour)
t_a = Free flow travel time on link (hrs)
V = Link volume (trains/day)
C = Link practical capacity (trains/day)
K_1, K_2, γ = Parameters

Within Clarke's formulation, he accounts for the control system (the signal system), the train power-to-weight ratio, the regions and the terrain type (flat or hilly). These values were derived from polynomial link delay curves developed by Bronzini and Sherman (1986). Within the context of implementation into TRAGIS, capacity studies conducted by Johnson (2009) applied this methodology to study on time performance for Amtrak and the impact of Amtrak on freight network capacity (Krier *et al.* 2014; Johnson, 2009).

Johnson's (2009) white paper on Amtrak performance provides a point of reference for understanding the implementation of rail capacity analysis on the railroad network. Within the White Paper, Johnson explained his internalization of Clarke's formulae to develop a capacity value for the ORNL Rail Network. In particular, Johnson explained the process for determining the geographic grade of the track that was necessary for completing the track calculation. In some cases, the rail carriers provided data and in other cases, Johnson developed an analogous method. His method required knowing the power of the locomotive moving the freight. From this value, he translated the power of the locomotive to the grade that train was traversing. Johnson acknowledged that in the cases where this analogous method did not work, manual inspection of topographic maps was used to calculate the gradient.

Using the method developed by Johnson, and by extension, Clarke has problems, particularly with implementation. First, Clarke's dissertation was based on polynomial delay curves from 1986 that used factors that were heavily steeped in operational knowledge (train power ratio, control system, track grade). Upscaling this for a planning tool such as TRAGIS requires the rail network to have these characteristics. The ORNL rail network includes the signal system, and sub-division is accounted for, but geography is not included. Likewise, the importance of terrain type and impact of grade is an important operational consideration (Dingler, Lai, and Barkan, 2014). Dingler, Lai, and Barkan (2014) acknowledge that rail link simulation with specific grade changes are necessary to effectuate a proper capacity measure, citing the work of Clarke (1995) and Bronzini and Sherman (1986) as their reference point.

Whereas the theoretical concerns raised by Dinger, Lai, and Barkan (2014) present fundamental issues, a more practical issue is the methodology used by Johnson (2009) in the identification of track grade. As Johnson (2009) originally reported, he determined geography based on the availability of track charts, the availability of locomotive tonnages, and then resorted to manual inspection. In trying to replicate his approach for this research, Norfolk Southern (NS) provided their track charts for inspection while other rail carriers were less cooperative. In addition, the locomotive chart developed by Johnson (2009) proved inapplicable since the track charts did not have the train power ratio. In an attempt to manually determine grade, a manual inspection of the study area was attempted. Using raster data obtained from the land surface cover map, an attempt was made to overlay the rail network with the topographic map of the study area to determine track grade. As Figure 4.8 illustrates, determination of track grade was complicated by numerous factors, including the fact that rail tracks were running between topographic lines and not across them and ultimately, the subjective nature in determining what is flat vs. hilly vs. mountainous terrain. In the case of Washington DC, while the Land Surface Form data may indicate a grade change, the contour lines indicate that the rail link has not changed grade significantly. In more geographically diverse states such as West Virginia and Virginia, where hills and mountains are more abundant, the rail lines would run along the riverbed. Although these rail links would be situated in mountainous terrain, the grade would indicate flat. At that point, the determination of grade was becoming less objective and more subjective.

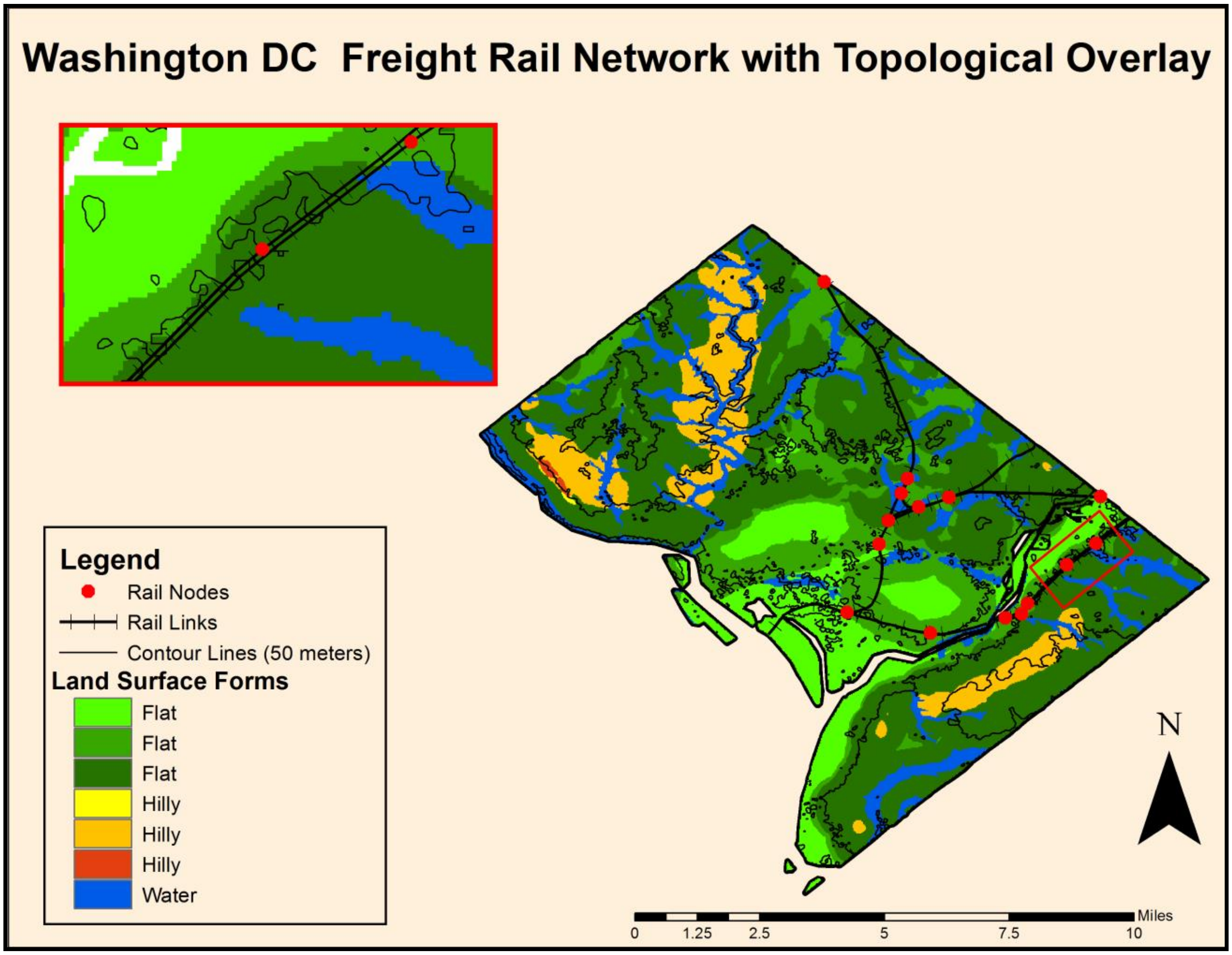

Figure 4.6: Issues with Rail Capacity Analysis
Data Sources: ORNL Rail Network and Land Surface Form Raster

To overcome this approach, which Mitra *et al.* (2010) describe as the delay-based approach to capacity analysis, Tolliver (2005) also illustrates the use of a theoretical zero-delay based capacity analysis, which ignores the geographic issues and some of the operational issues encountered in applying the Clarke-Johnson approach. Under the theoretical zero-delay approach, the primary focus is on the calculation of the minimum headway (distance between) trains. The headway becomes a function of the block length (the spacing between trains), the train length, the speed of the train, and the number of signal aspects. The signal aspect represents the signal system type, with more sophisticated signals having more signal aspects (Tolliver, 2005). To calculate the theoretical zero delay capacity, the first step is to calculate the minimum headway, as represented in Equation 4-2

$$H_{\min} = \frac{L_B\left(N_s - 1\right) + L_T}{v} \quad \textbf{(4-2)}$$

where

H_{min} = Minimum time headway (in hours)
L_B = Block length (in miles)
L_T= Train length (in miles)
N_S = Signal aspects
v = speed (mph)

Once headway is calculated, a theoretical link capacity per day can be obtained by taking the minimum headway value and dividing by 24 hours as shown in Equation 4-3:

$$T_{\max} = \frac{24}{H_{\min}} \quad \textbf{(4-3)}$$

where

T_{max} = Theoretical Capacity
H_{min} = Minimal headway

Having calculated the theoretical capacity, the practical capacity is calculated using an operating value of 70%, which is consistent with the practical capacity value discussed by Abril *et al.* (2007).

For the purpose of this research, some operating values will be assumed for the minimum headway calculation. Using similar assumptions used by Dingler, Lai, and Barkan (2014), the train length, signal aspect value, and the block length will be fixed values. In their research, Dinger, Lai, and Barkan (2014) used Rail Traffic Controller (RTC) to calculate capacity values for a stylized situation to analyze single track freight haulage. In their simulation, they assumed a block length of 2.75 miles and assign a value of 3 for the number of signal aspects. With regard to train length, they compare intermodal train length (5659 ft. = 1.07 miles) with bulk train length (6325 ft. = 1.20 miles). This research assumes an average train length of 1.1 miles (5808 ft.). With those assumptions, Equation 4-2 looks like the following:

$$H_{\min} = \frac{2.75\left(3-1\right)+1.1}{v} \quad = \quad H_{\min} = \frac{6.6}{v}$$

Other than the speed, the remaining values become constant, with the speed being the variable for headway. Within the railway network of TRAGIS, there is a speed value for each link within the network, based on the allowed speeds as determined by the track class designation of that particular link.

Once the theoretical and practical values are calculated, CCWS fields for carloads are prepared. The carload value within the waybill record is converted into train size (approximately 110 carloads per train), then divided by 365, the number of days railroads operate yearly (LoSapio, 2017). Finally, the actual value is compared against the practical and theoretical values.

4.7 Summary

In this chapter, a set of research questions were outlined to analyze the Jones Act's effects on freight transportation. The chapter focused on describing the research design considerations, the datasets used, and the proposed methodology for analyzing the impact of the Jones Act on the movement of goods in the aftermath of a disruption.

While this chapter discussed the datasets used, this research asks how these datasets can be used within existing GIS programs to study policy-based research questions. The next chapter provides a brief history behind TRAGIS and Oak Ridge National Laboratory's programmatic interest in transportation research. In addition, the chapter provides a procedure for taking the FAF and CCWS and processing the data through the TRAGIS routing engine. These procedures address Question 2 and introduce a process for taking transportation data and converting it into geo-spatially enabled routes for visualization in GIS. These procedures provide an opportunity for studying legal and policy questions, such as the effect of the Jones Act on the freight transportation networks.

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Chapter 5: WebTRAGIS and Data Conversion[6]

5.1 Introduction

Chapter 4 introduced the research questions for this dissertation; namely, what effect does the Jones Act have on freight transportation networks experiencing a disruptive event. Question 2 in Chapter 4 asked how existing transportation datasets could be leveraged to study the effects of law and policy on transportation networks. Chapter 4 introduced two datasets, the Freight Analysis Framework and the Confidential Carload Waybill Sample (CCWS). Both of these datasets are economic data sets, with limited geo-spatially explicit data. Because of the cross-disciplinary nature of this research, Chapter 5 includes detailed descriptions of the underlying tools and algorithms for those not familiar with transportation geography and graph theory. This chapter introduces the WebTRAGIS platform. Particular emphasis is placed on the evolution of WebTRAGIS from its legacy systems, after which the modeling algorithms and computational implementation involved in routing individual modes are explained. The chapter describes the process for converting the FAF and the CCWS from their existing forms into geo-spatially routable data for subsequent processing and implementation and visualization in WebTRAGIS. Finally, the chapter concludes by focusing on the validation analysis used to assess the validity of the routes generated by the TRAGIS routing engine.

5.2 History of Web Transportation Routing Analysis GIS (WebTRAGIS)

The use of Geographic Information Systems (GIS) to study transportation problems is a useful tool for planners, geographers, engineers, and decision-makers. Few contributions in the field of transportation geography add more value than that of GIS technology (Black, 2003). In the context of transportation analysis, GIS supports an in-depth analysis of transportation policies (Macharis and Pekin, 2008). Through the development of "virtual" networks to illustrate intermodal networks (Southworth and Peterson, 2000), GIS has become a valuable tool to freight planning and research.

Over the past thirty-five years, researchers at Oak Ridge National Laboratory (ORNL) have taken a programmatic interest in the planning, transportation, and security issues related to transporting hazardous materials, particularly Spent Nuclear Fuel (SNF) and High Level

[6] Portions of this dissertation chapter were used in the following publication:
Fialkoff, M.R.; Peterson, S.K.; Hancock, K.L. (under review). Putting the Spatial into Non-Spatial Data: Implementation of the Confidential Carload Waybill Sample for Routing Railroad Freight Flows. *Currently under review by the Journal of the Transportation Research Forum*.

Radioactive Waste (HLRW) (Peterson, 2016). In response to Department of Energy (DOE) mission objectives in the safe disposal of SNF and HLRW, ORNL developed various transportation networks and routing models for highway, railway, and waterway analysis. Starting in the late 1970s, two transportation routing analysis tools supported efforts to study the potential effects of transporting SNF and HLRW. The first model, HIGHWAY, predicted highway (truck) routes and the second model, INTERLINE, predicted railway and waterway routes. Over time, these models became what is currently known as TRAGIS (WebTRAGIS).

5.2.1 Legacy Systems: HIGHWAY and INTERLINE

TRAGIS is the outgrowth of two legacy systems previously developed by ORNL to study transportation routing of SNF, HLRW, and other hazardous materials. The genesis of the these models came from DOE programmatic interests in understanding the population impacts of transporting radioactive material through different urban settings and the routes which would efficiently and safely transport the material to its ultimate destination (Peterson, 2016).

In their earliest iterations, the HIGHWAY and INTERLINE networks were small. The highway network consisted of approximately 20,000 highway segments (links) and 13,000 intersections (nodes) (Johnson, 1993a). The railroad and waterway networks consisted of 15,000 rail and barge links and 13,000 stations, interchange points, ports, and other nodes (Johnson, 1993b). In comparison to the current ORNL transportation networks, these initial networks are considerably smaller. In HIGHWAY, a naming convention was developed to describe the particular link and intersection depending on the Interstate, U.S. Highway, state highway, turnpike, or county road for that particular segment. In contrast, the naming convention developed for INTERLINE had more in-depth information associated with each link, particularly for mainline classification (MLC), a measure of traffic volume for a particular link (Johnson, 1993b). In addition to the MLC, the links identified the owner of a particular link in addition to identifying trackage and haulage rights for railroads in the network.

For purposes of routing in both models, HIGHWAY and INTERLINE implemented a shortest path algorithm for routing through the respective networks. In both instances, the algorithms modified over time to account for operational characteristics for traveling on road, rail, and water (Johnson, 1993a; Johnson, 1993b). For HIGHWAY, the shortest path algorithm was adjusted to account for multiple drivers and a trade-off between shortest path (distance) and fastest travel time. In addition to these operational considerations, HIGHWAY accounted for regulatory restrictions on the movement of hazardous materials; specifically, links identified as Highway Route Controlled Quantity (HRCQ) or HazMat as promulgated by the relevant agency. With these routes, links designated HRCQ or HazMat are the only permitted links for moving these particular cargoes.

In the INTELINE algorithm, the rail and waterway routing algorithms were more complex. Particular emphasis was placed on specific operational considerations such as the MLC, the waterway type, and the starting and ending railroad company. In addition, the algorithm penalized rail transfers by both increasing travel time and increasing the impedance value for the route. *Impedance* accounts for operational considerations within each mode that may slow down, increase distance, or increase travel time for a potential route within a particular mode. For example, if there is a transfer between two rail companies or a transfer from inland waterway to ocean-going waterway, the algorithm will apply a default transfer penalty and increase the time based on default waiting times (which account for transfer between rail companies or cargo movement between two vessels). In this case, the impedance value is akin to a friction factor, or the ease with which a given route encounters operational issues.

Although based on principles of network analysis and ensuring accurate implementation of the various algorithms, the visualization for HIGHWAY and INTERLINE was limited. The primary outputs for both models were text-based descriptions of the various routes. Both models did provide options for blocking particular nodes to study alternative routes, though the visualization and subsequent outputs required proficiency in computer programing to generate outputs. From 1979 until the early 1990s, HIGHWAY and INTERLINE were the predominant routing tools used for transportation analysis in this area of research.

5.2.2 From HIGHWAY and INTERLINE to TRAGIS

While HIGHWAY and INTERLINE provided data-rich text outputs for transportation routing analysis, both models suffered from several drawbacks. A drawback to HIGHWAY and INTERLINE involved the lack of user interface and the limited visualization of the route outputs. Neither HIGHWAY nor INTERLINE generated maps, but produced text-based descriptions of the routes and provided basic stick figure representations of the output routes (Johnson 2003). Furthermore, both models required the user to have programming proficiency with adjusting the code to account for desired operational characteristics. This made the program not readily accessible to lay-people, unless they read the user manual.

Following a baseline review of the programs in 1994, the DOE Office of Environmental Restoration and Waste Management (EM) Transportation Management Division (EM-261) determined that an update of the existing models was required. Given the advancement in GIS technology, a new routing model was necessary that could generate the routes in a visual medium, in addition to the text-based descriptions provided by HIGHWAY and INTERLINE (Johnson and Michelhaugh, 2003). It is from these recommendations that the TRAGIS program started.

Over the course of twenty years, TRAGIS evolved from its legacy programs to a more robust and user-friendly application. In the early iterations of TRAGIS, the program required installation on the user's personal computer. The current iteration of TRAGIS is a thin client-based program developed to be accessible over the internet with an easy to use Graphical User Interface (GUI) (Peterson, 2016). As a web-based application, TRAGIS became known as WebTRAGIS. Since WebTRAGIS supports current DOE mission objectives, access is restricted to those individuals supporting DOE research or prior permission from DOE, with access requiring a login and password as shown in Figure 5.1.

Figure 5.1: WebTRAGIS login screen
Source: WebTRAGIS-ORNL: https://webtragis.ornl.gov/tragis/app/login

Figure 5.2 illustrates the GUI for WebTRAGIS, which provides registered users with platform to generate routes, although the main routing engine is located on a server at ORNL.

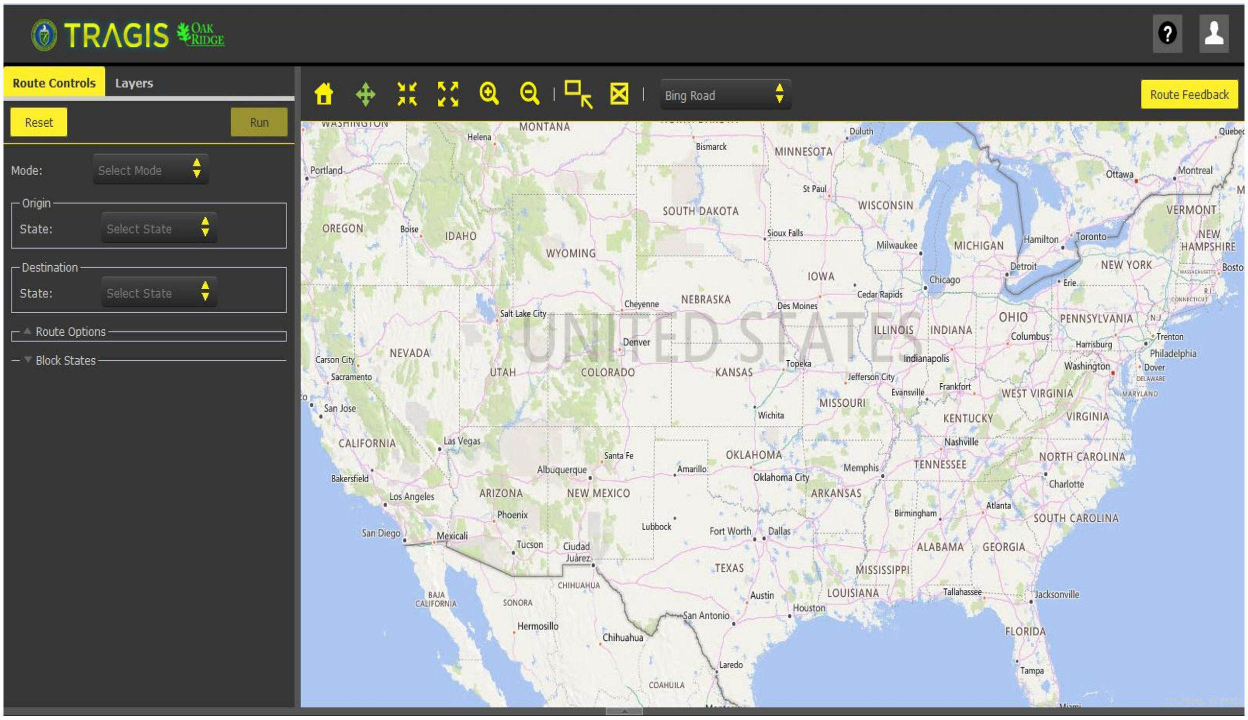

Figure 5.2: WebTRAGIS Graphical User Interface
Source: WebTRAGIS-ORNL: **https://webtragis.ornl.gov/tragis/app/map/view**

The GUI in WebTRAGIS addresses the concern of a user-friendly interface that allows for efficient operation of the tool. In addition to the GUI, individual users can also use a specialized batch program that allows users to generate multiple routes from one file. Unlike the WebTRAGIS platform, the batch program requires users to create .CSV files and submit them to ORNL for processing, as there is currently no GUI for registered users.

The TRAGIS routing engine program is C++ and resides on the server at ORNL (Peterson, 2016). When a user inputs particular route parameters into WebTRAGIS from their personal computer, that information passes through the routing engine. From there, depending on the mode selected, the algorithm for a particular mode begins to calculate the desired route based on the inputs selected by the user. Once the route generates, a series of summary reports detailing route details, population densities, and critical infrastructure is available for the user. The summary outputs, including the GIS files transmit over the Internet back to the user. Users may then save, delete, or download route information for use in GIS platforms such as ArcMap.

Figure 5.3 illustrates the system architecture for WebTRAGIS and subsequent workflow for generating routes from the route engine.

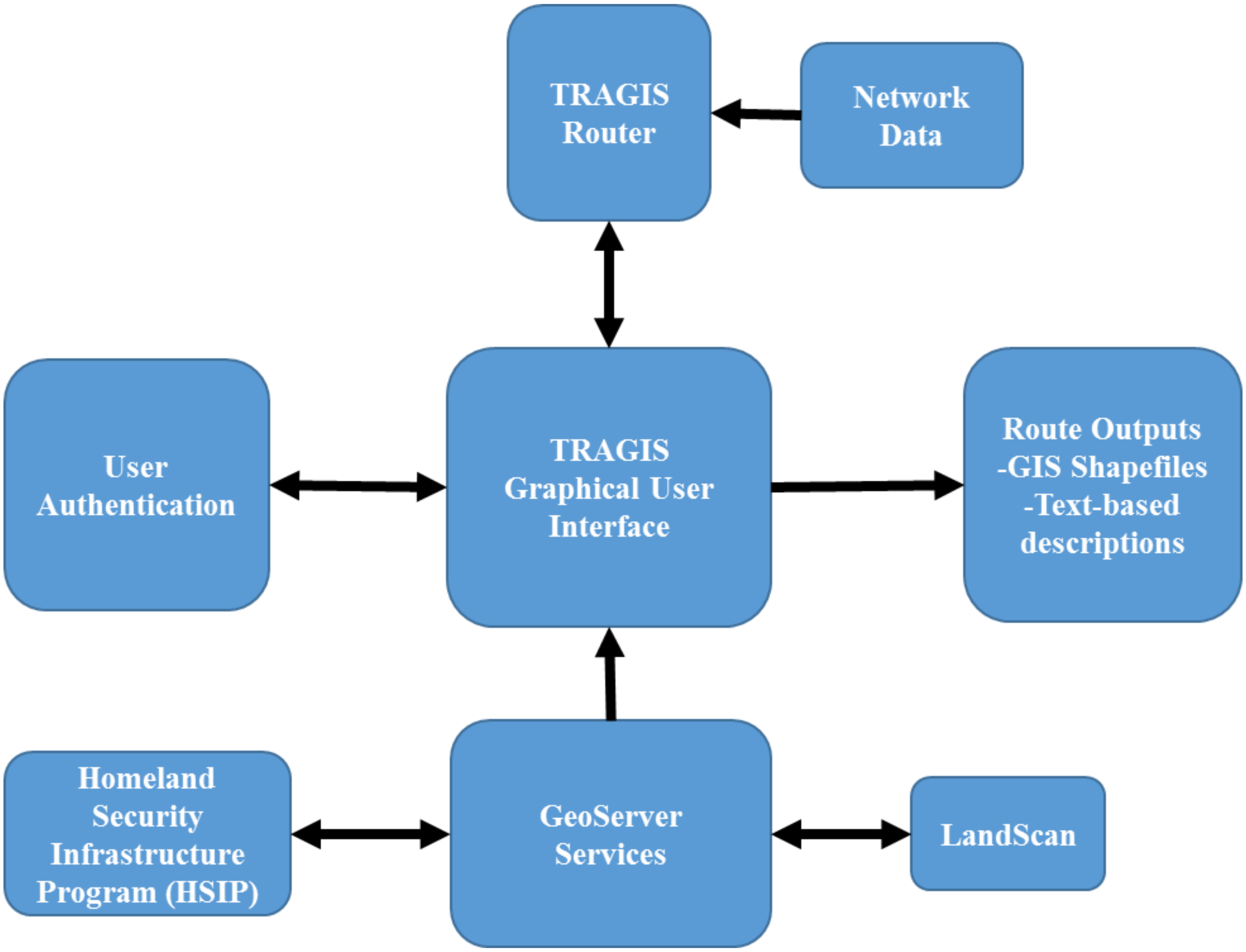

Figure 5.3: System Architecture of TRAGIS
Source: Adapted from Peterson (2016)

In contrast to the legacy models of HIGHWAY and INTERLINE that used "stick figure" representations, WebTRAGIS offers more detailed representations of the rail, road, and water networks (Johnson and Michelhaugh, 2003). The data used to generate the detailed networks comes from the U.S. Geological Survey Digital Line Graphs, the U.S. Census Bureau Topographically Integrated Geographic Encoding and Reference (TIGER) System, the U.S. Army Corp. of Engineers, the Federal Motor Carrier Safety Administration (FMCSA), the Federal Railroad Administration (FRA), and high-resolution satellite imagery (Peterson, 2016).

In addition to generating transportation routes from the networks, TRAGIS pulls information from LandScan, the population database, also developed at ORNL, and the Homeland Security Infrastructure Program (HSIP) data layers, as illustrated in Figure 5.3. The population density results generated in WebTRAGIS can be exported to radioactive transportation risk programs such as RADTRAN to measure the risk of transporting hazardous materials through various geographic regions (Weiner *et al.*, 2013)

5.3 Current WebTRAGIS Algorithms and Transportation Networks

The previous section explained the evolution of WebTRAGIS, tracing its origins to HIGHWAY and INTERLINE. While the original mission of WebTRAGIS was routing analysis for SNF and HLRW, Georgia Tech Research Corporation *et al.* (2012) acknowledged that tools such as WebTRAGIS can be used to study the effect of disruptions on freight transportation. In particular, the report recognizes WebTRAGIS specifically as a simulation based tool for studying disruptions in the freight network.

This section presents the algorithms that are currently used for the individual modes within the program. The discussion also describes the network attributes for each of the transportation modes, primarily the size and operating characteristics related to each network. The section illustrates how the algorithms work using the attributes present for each of the networks in the programs to calculate particular routes for each mode.

5.3.1 The Highway Network and Routing Algorithm

The current highway network developed from a 1:100,000-scale road network derived from the U.S. Geological Survey digital line graphs and the U.S. Census TIGER data. The network represents slightly over 237,000 miles and includes all U.S. Interstate highways, most U.S. highways except those that closely parallel Interstate highways, most major state highways, and other local roads (both county and city) connecting to various specific sites of interest (Peterson, 2016). Within the current highway network, there are 21,000 highway links and almost 15,000 intersections (nodes), as illustrated in Figure 5.4.

Because the original mission of WebTRAGIS focused on Spent Nuclear Fuel and High Level Radioactive Waste transportation, the network includes nodes for commercial nuclear power plants, DOE sites such as National Laboratories and research facilities, commercial airports (designated by their location identification), and military airports (also designated by their location identification). A GIS distance measuring technique using an equidistant projection is used to calculate the distance (in both miles and kilometers) of each link in the network (Peterson, 2016). In addition to link length, other attributes in the highway network include speed limit, toll designation, commercial truck restrictions, preferred route designation for HRCQ shipments, and non-radioactive hazardous material route restrictions.

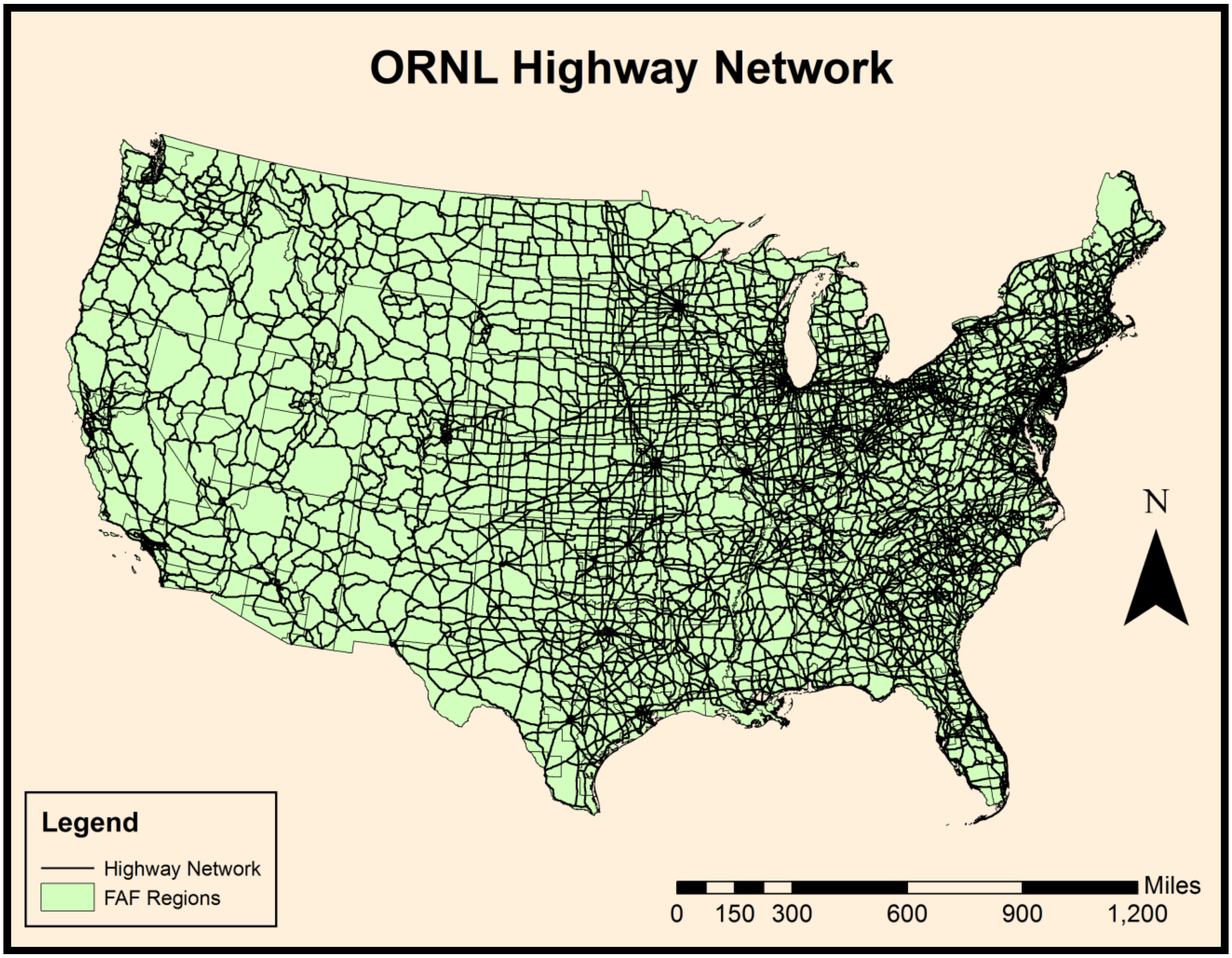

Figure 5.4: ORNL Highway Network
Data Source: Peterson (2016)

The algorithm can generate routes that meet the U.S. Department of Transportation (DOT) regulations for the shipment of HRCQ radioactive materials, non-radioactive material, non-HRCQ hazardous materials, and routes for shipments to the Waste Isolation Pilot Plant (WIPP) located near Carlsbad, New Mexico.

The algorithm used for highway routing is similar to the one used in the original HIGHWAY model previously discussed. The algorithm, based off the shortest path algorithm, employs the following objective function for determining the impedance, *L*, over a route with *i* segments and represented in Equation 5-1 as:

$$L = Min\sum_{i}\left(\alpha D_i + \beta T_i\right) \quad \textbf{(5-1)}$$

where

L = total impedance of a route;
α = distance bias;
D_i = distance of segment i, miles;
β = time bias;
T_i = time required to travel along segment i, minutes.

Setting the values for the distance time biases defines a particular routing criterion. The default biases for commercial shipments, α and β, are 0.3 and 0.7, respectfully. These values can be altered if the user desires a true shortest path or a faster travel time.

5.3.2 The Railway Network and Routing Algorithm

In contrast to the highway network, the operating complexities involved with railways and the network heterogeneity require a more detailed routing algorithm and more attributed network that represents the U.S. railroad network. In contrast to the network used for INTERLINE, which developed from a 1:100,000-scale network derived from the United States Geologic Survey digital lines graph, Peterson (2016) explained that the revised network uses high-resolution satellite imagery to improve the topological accuracy of the rail alignments and placement of the nodes. The current rail network used by WebTRAGIS consists of over 94,000 links and over 35,000 nodes representing approximately 143,000 miles of mainline and branchline track, as illustrated in Figure 5.5.

The numbers described above represent the *routable* railway network, meaning that this network consists of all the active rail lines in the United States. Although not considered routable, included in the rail network, are industrial spurs, yard track, and sidings. In contrast to the highway network that uses intersections as nodes, the railway network nodes are the station locations as registered by the rail carriers. Each station or depot has a Standard Point Location Code (SPLC). The SPLC helps rail carriers identify locations where they operate as owner or have a trackage or haulage right. The SPLC is a six to nine digit geographic code representing a physical location for a rail station. In addition to the standard SPLC nodes, the network includes nodes for nuclear reactor sides, rail accessible coal-fired power plants, DOE sites such as National Laboratories, and military bases with rail lines. Unlike the highway network, the rail network is continuously updated and revised on a regular basis to reflect line abandonment, rail carrier mergers, creation of new short-lines, and new rail construction (Peterson, 2016). The continual update of the network is meant to ensure the network reflects current conditions to support DOE mission objectives.

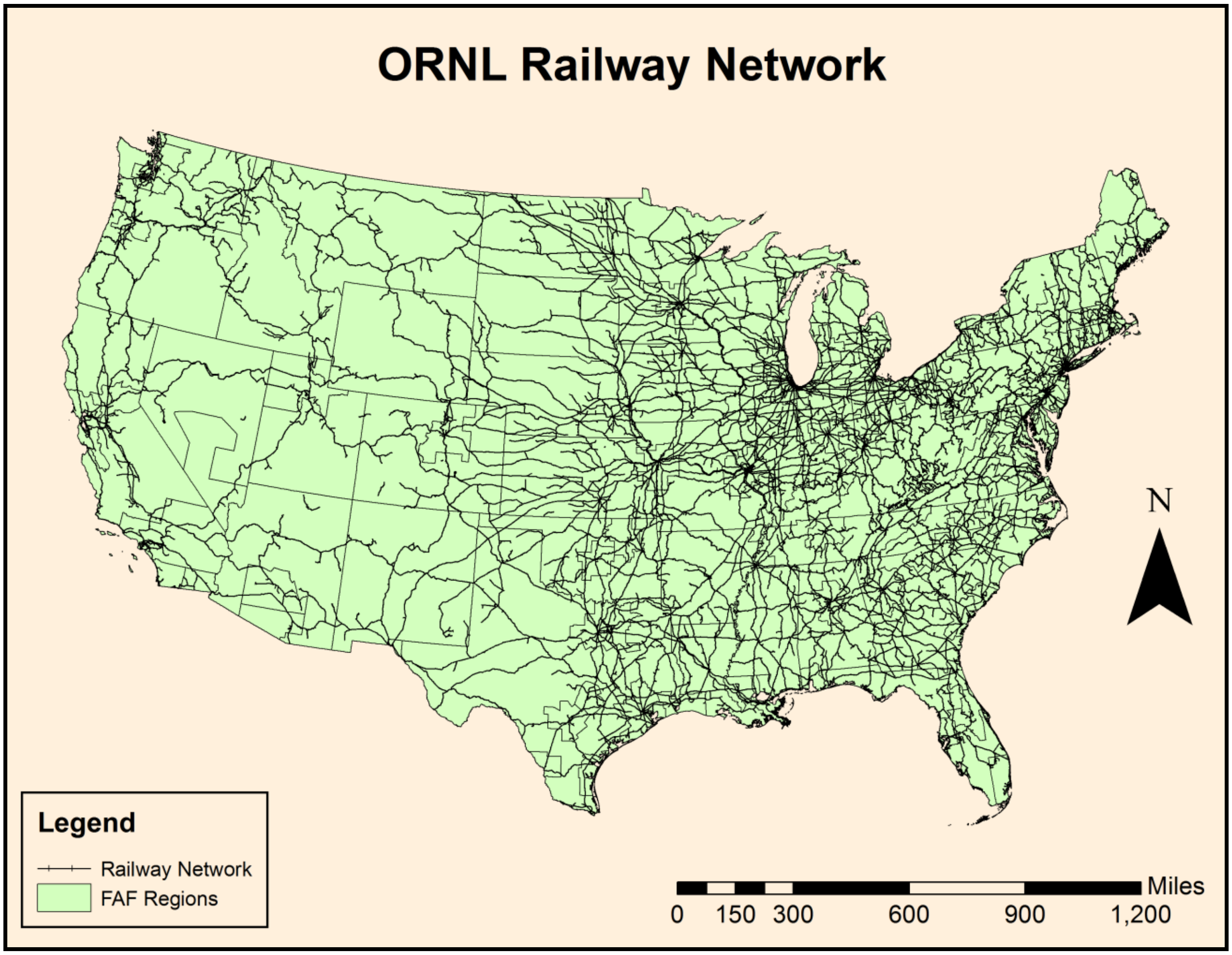

Figure 5.5: ORNL Railway Network
Data Source: Peterson (2016)

One attribute within the rail network is the current state of ownership for the railroad sector in the United States. There are currently over 500 different railroad companies operating in the U.S (Peterson, 2016). Although there are over 500 different rail carriers, not all railroads are equal. Over time, consolidation and reorganization of the rail carriers have led to the formation of seven major railroads. These railroads carry the bulk of U.S. freight rail traffic and account for 69% of the rail mileage in the United States and cover forty-four states (Class I Railroads). These railroad companies include the Burlington Northern Santa Fe Railway (BNSF), Canadian National (CN), Canadian Pacific (CP), CSX Transportation (CSXT), Kansas City Southern (KCS), Norfolk Southern (NS), and Union Pacific (UP). As Figure 5.6 illustrates, the Class I railroads traverse the continental United States, with many of the Class I railroads entering into interlining agreements with other Class I carriers to ensure transcontinental service.

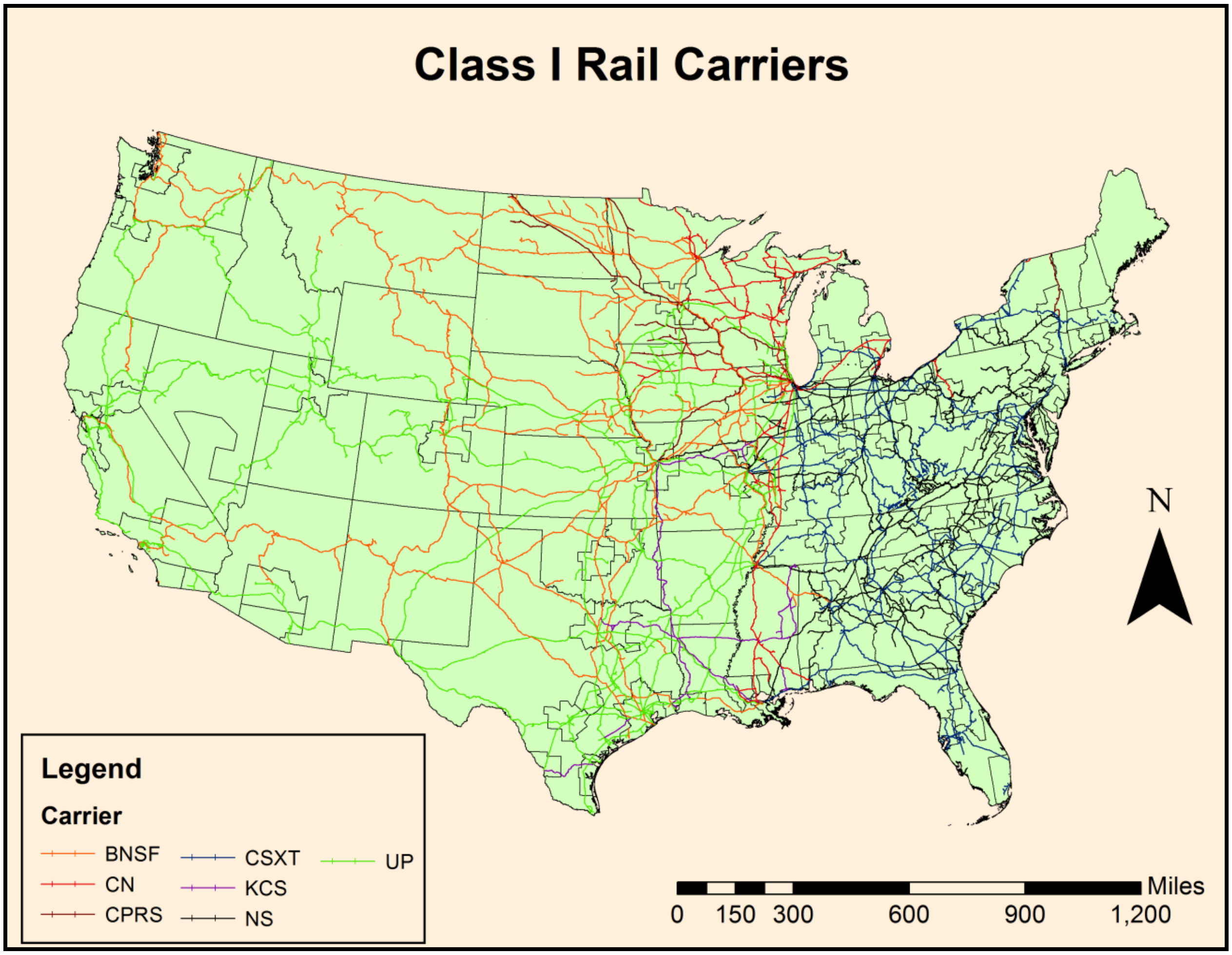

Figure 5.6: Class I Rail Carriers in the United States
Data Source: Peterson (2016)

In addition to these Class I railroads, there are many railroads that are small and operate over small distances of track. These railroads are known as short lines or trunk lines and link Class I lines across the United States.

Similar to the algorithm used in the INTERLINE model, the rail routing algorithm in WebTRAGIS follows a similar objective function that calculates an impedance, *L*. Given the increased operating characteristics taken into consideration for generating rail routes, the objective function is slightly different, as presented in Equation 5-2:

$$L = Min\left\{\sum_i \left(\sigma_i f_i d_i\right) + \sum_n \left(T_n\right)\right\} \quad \textbf{(5-2)}$$

where

L = total impedance of a route;

σ_i = railroad factor for link i, with
= 0.8 for the originating railroad,
= 1.0 for all other railroads;
f_i = mainline classification factor for link i, with
= 1.0 for A-mainline,
= 1.2 for B-mainline,
= 1.6 for C-mainline,
= 1.9 for A-branchline,
= 4.0 for B-branchline,
= 6.0 for C-branchline;
d_i = distance along link i, in miles;
T_n = transfer penalty factor at node n, with
= 151.0 for a terminal transfer,
= 300.0 for a primary transfer,
= 400.0 for a minor transfer,
= 1500.0 for a detour transfer.

Similar to the highway routing algorithm, the rail routing algorithm has two options for generating routes. The first option, the standard train option, preserves the ownership structure of the rail network and penalizes transfers to different rail carriers (both in time and impedance). The second option is a dedicated train option. Originally conceived for allowing trains carrying SNF or HLRW material to ignore the rail carrier ownership and traverse the network as though the ownership was network neutral. For purposes of this research, the routes generated use the standard train route option to reflect current rail interlining and operational characteristics.

5.3.3 The Waterway Network and Routing Algorithm

The third and final modal routing option in WebTRAGIS involves water-borne transportation. Using the National Waterways network developed by the U.S. Army Corps of Engineers, the waterway network was simplified to represent the major topological features for maritime transportation (Peterson, 2016). Specific changes from the Army Corps network included a reduction in the number of nodes from 19,000 to 4,000 and a similar reduction in links from over 21,000 to approximately 4,600, representing 160,000 miles of domestic and international waterways and shipping lanes. During the simplification process, high-resolution satellite imagery was used to re-draw links to reflect topological accuracy. In addition, the links in the waterway network are classified to indicate particular geographic locations associated with these links. During this process, links were classified as either shallow draft inland waterways, designated “IWW,” or deeper draft commercial inland waterways as “CIWW,” while the various coastal waterways were given appropriate designations: “AICW” for the Atlantic Intracoastal

Waterway, "GICW" for the Gulf Coast Waterway, and "PCWW" for the Pacific Coast Waterway. Links in the Great Lakes are given the designation of "GLK" and the ocean-going commercial shipping lanes are designated "OCM" (Peterson, 2016). Figure 5.7 illustrates the waterway network with particular emphasis given to the domestic waterway network that consists of navigable rivers and the intercoastal waterway system..

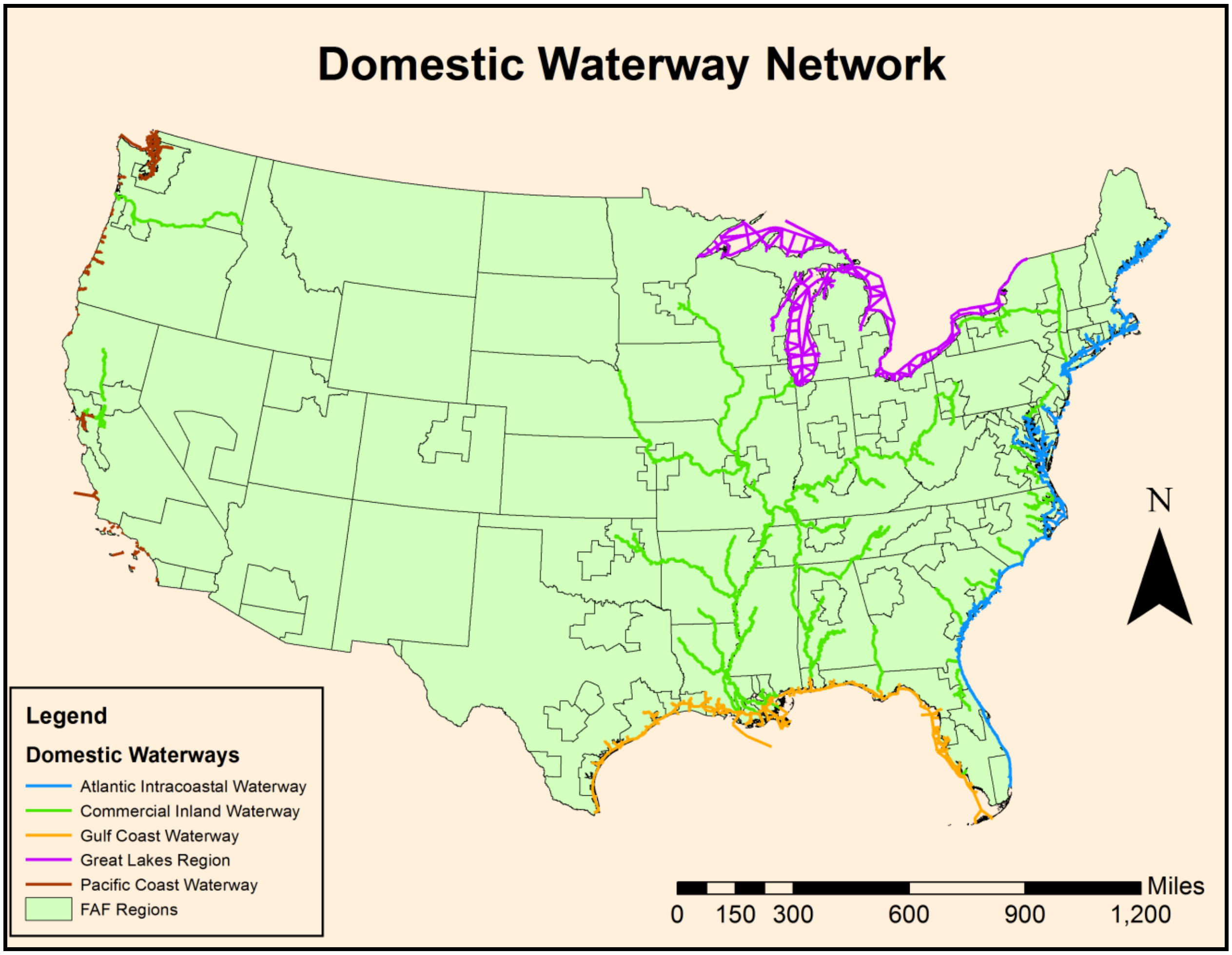

Figure 5.7: Selected portions of ORNL Waterway Network
Data Source: Peterson (2016)

Similar to the railway routing algorithm, the waterway routes are generated by minimizing the total impedance, *L*, between the origin and destination. As Peterson (2016) explains, the impedance value is calculated using a similar objective function to that of the railroad equation as represented in Equation 5-2. In contrast, the waterway Equation, as shown in Equation 5-3 generates routes based on waterway type and whether the waterway is a shallow or deep draft.

$$L = Min\left\{\sum_i \left(f_i d_i \right) + \sum_n T_n \right\} \quad \textbf{(5-3)}$$

where

L = total impedance of a route;

f_i = weighting factor for link i, with

= 1.0 for ocean commercial marine,

= 1.0 for commercial inland waterways,

= 1.2 for coastal waterways,

= 1.5 for Great Lakes, and

= 2.5 for shallow-draft inland waterways;

d_i = distance for link i, in miles;

T_n = transfer penalty factor at node n.

In comparing the waterway routing algorithm with the railway routing algorithm, there is no σ_i because no originating company *per se* exists in waterway routing. Similarly, the waterway algorithm omits the mainline and branchline classifications, as they are not operationally necessary.

5.4 Converting FAF and CCWS Datasets into Geospatial Routes for TRAGIS

Chapter 4 introduced the Freight Analysis Framework (FAF) and the Confidential Carload Waybill Sample (CCWS) as the primary data sources used to conduct the analysis in this dissertation. Both these datasets contain economic data of commodity flows across the United States for both road and rail haulage. The CCWS is used instead of the FAF rail data because the CCWS provides interchange information and rail carrier information, ensuring a more accurate representation of the routes generated.

One of the challenges with using economic data such as the FAF and CCWS is limited geo-spatial data that allows for easy implementation and visualization in GIS programs, or for that matter, allowing the data to be flowed over existing transportation networks such as those supporting WebTRAGIS. Although the FAF does have a companion network that FHWA uses to allow visualization of the freight flow for the road haulage, no such companion network exists for the other modes that the FAF supports. The next two sections describe the process undertaken to convert FAF and CCWS flow data into routable information for the TRAGIS routing engine.

5.4.1 Conversion of FAF Highway Data

Prior to generating routes or flowing commodity data over the highway network used in WebTRAGIS, the FAF economic data needs to be converted (more aptly, geographically calibrated) to the highway network used by WebTRAGIS. The data structure within the FAF provides a zone-to-zone, origin-destination, movement of commodities. According to the Center for Transportation Analysis (CTA) at ORNL, there are 132 FAF regions for the whole United States, including Alaska and Hawaii (CTA, 2015). As Figure 5.8 illustrates, these regions are broken up according to population and metropolitan size, similar to the Metropolitan Statistical Areas (MSAs) used in the Commodity Flow Survey (CFS). In the FAF, some MSAs are combined into Census Metropolitan Areas (CMAs). These CMAs may cross state boundaries as acknowledged in the CTA Report (2015).

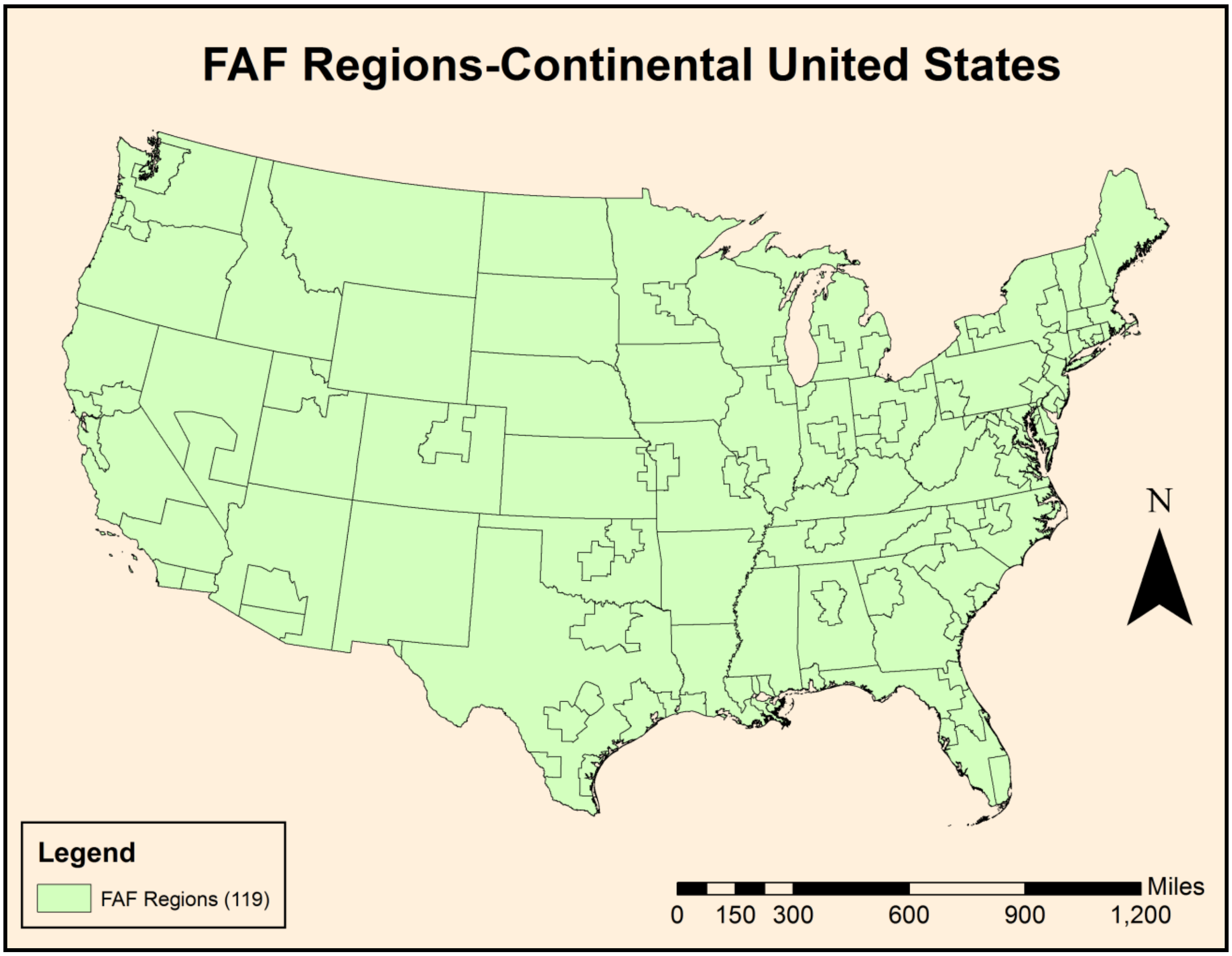

Figure 5.8: FAF Regions for the Continental United States
Data Source: Federal Highway Administration: https://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf3/netwkdbflow/

From the information provided in Chapters 2 and 4, the study area consists of traffic diverted to Norfolk and subsequent dispersion of freight out of the Port of Norfolk; specifically, the Norfolk International Terminal (NIT). In Chapter 4, the discussion focused on the study area for the highway analysis, citing research by Resor (2004) and Resor, Blaze, and Morlok (2004) that determined that the economic tipping point between road haulage and rail haulage was approximately 300-350 miles. For purposes of this analysis, a 300 mile radius determined which FAF regions would be used for the highway analysis. As Figure 5.9 illustrates, a 300-mile radius around NIT resulted in a study area ranging as far south as South Carolina to as far north as New York, with an westward extension to the western boundaries of Virginia, West Virginia, and Pittsburgh, Pennsylvania.

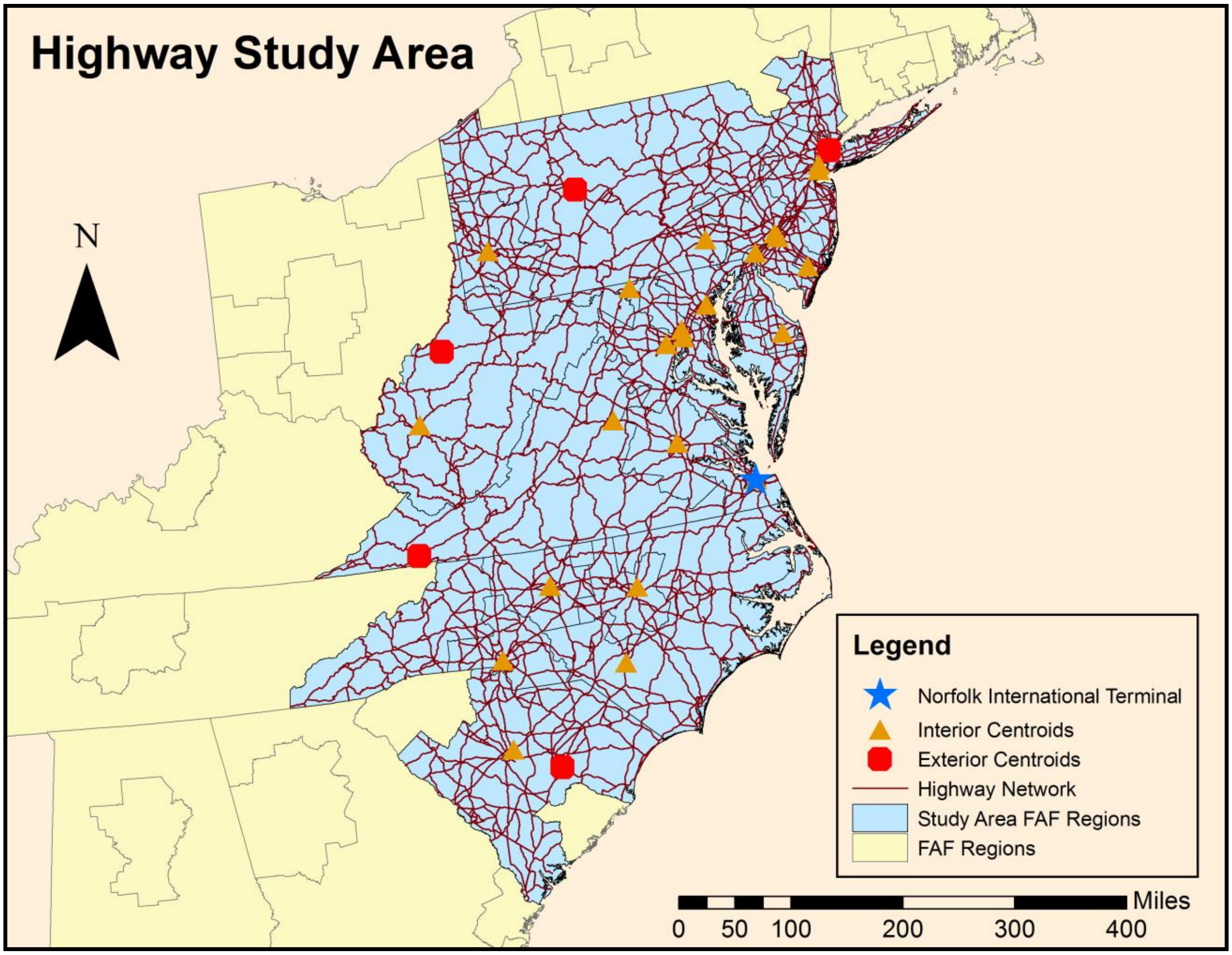

Figure 5.9: Highway Study Area
Credit: M. Fialkoff (2017)

A perennial challenges associated with freight relates to disaggregation of the data from the zonal data to a county, or more local attribution of freight movement between origin and destination. To calibrate the FAF to the highway network, the zonal data had to be focused on a highway node within each of the FAF regions within the 300-mile buffer as illustrated above. For this research, interior centroids were matched to the highest population centers within each of the FAF zones. Once the population center was determined, the population center location was located within the highway network node database. A similar process determined exterior centroids for traffic entering and leaving the study area. The red octagons in Figure 5.9 represent major interstates or U.S. highways exiting or entering the zone. These exterior centroids are tied to major population centers outside the study area, such as Boston, Chicago, Memphis, St. Louis, and Jacksonville. Table 5.1 shows the Interior Centroid calibration, with the FAF Region associated with the FAF dataset, the determined population center, its corollary within the highway network, and the subsequent highway node ID.

Table 5.1: Interior Centroid Calibration

ID[7]	FAF Region	ORNL Highway Node Name	TRAGIS Highway NodeID
A	Baltimore	DUNDALK PORT	24000004900
B	Charlotte	CHARLOTTE I277I77	37000008500
C	DC Part-Washington	WASHINGTON U1 U50	11000002000
D	DE Part-Philly	WILMINGTON N I95 X8	10000002000
E	Greensboro	GREENSBORO I73I40	37000014400
F	Maryland Part-Washington	SILVER SPRING U29 S97	24000004900
G	NJ Part-NYNJPACT	PORT OF NEWARK	34000007000
H	NJ Part-Philly	CAMDEN S I676I76	34000007200
I	Norfolk	NORFOLK INTL TM	51000012700
J	NY Part-NYNJPACT	STATEN ISLAND W I278X9	36000008200
K	PA Part-Philly	PHILADELPHIA I676I95	42000010600
L	Pittsburgh	PITTSBURGH I279I376	42000010400
M	Raleigh Durham	RALEIGH I540U401	37000014500
N	Remainder of Delaware	GEORGETOWN U9 S404	10000002000
O	Remainder of Maryland	HAGERSTOWN W I81 X6	24000004800
P	Remainder of New Jersey	MAYS LANDING U40 S50	34000007300
Q	Remainder of North Carolina	FAYETTEVILLE S I95 X40	37000008500
R	Remainder of Pennsylvania	LANCASTER NW U30 S283	42000010500
S	Remainder of South Carolina	COLUMBIA NE I20 I77	45000010900
T	Remainder of Virginia	CHARLOTTESVL E I64 X124	51000012500
U	Richmond	RICHMOND NW I64 I95	51000012600
V	Virginia Part-Washington	FAIRFAX U50 S236	51000012500
W	West Virginia	CHARLESTON NE I77 I79	54000013800

Credit: M. Fialkoff (2017)

A similar table, Table 5.2, shows the exterior centroids. In contrast to the interior that focused on population center, the exterior centroids followed Interstates and U.S. Highways. While the five centroids represent population centers outside the study area and become

[7] The ID numbering scheme used by the author truncated the names of the FAF region during the calibration phase.

important in the commodity assignment, the exterior nodes were locations just outside the 300-mile buffer, but along the major routes as shown below.

Table 5.2: Exterior Centroid Calibration

ID[8]	FAF Region	ORNL Highway Node Name	State	TRAGIS Highway NodeID
1	Jacksonville	ALCOLU SE I95 X122	SC	45000010900
2	Memphis	ABINGDON E I81 X19	VA	51000012700
3	St. Louis (MO Part)	ELLENBORO S U50 S16	WV	54000013800
4	Chicago (IL Part)	NEEDFUL S I80 X123	PA	42000010200
5	Boston (MA Part)	BRONX SW I87 I95	NY	36000008100

Credit: M. Fialkoff (2017)

Once the annual truck traffic and daily truck traffic values were calculated, they were appended to the batch file for the highway routing file. Similar to the rail batch file, Table 5.3 illustrates the attributes needed for the batch process to generate routes in CSV format.

Table 5.3: TRAGIS Batch Format for Highway Route Generation

Attribute	Explanation
RouteID	
RouteName	Zone-to-Zone Name
Mode	Highway
Origin Mode	Origin Mode-Highway
Origin Node	Origin Node ID
Origin Company	Truckload

Attribute	Explanation
Destination Mode	Destination Mode-Highway
Destination Node	Destination Node ID
Destination Company	Truckload
Annual Trucks	Annual Truck Traffic
Daily Trucks	Daily Truck Traffic

Credit: M. Fialkoff (2016)

5.4.2 Conversion of CCWS Rail Data

In contrast to the conversion and calibration of the FAF information into routable data for the highway routing algorithm, conversion and calibration of the Confidential Carload Waybill Sample (CCWS) into routable data for the railway network is a multi-step process, involving multiple railway databases associated with the railway network. The complexity involved with railway routing stems from multiple issues:

- identifying trackage and haulage rights for rail carriers in the network,
- identifying interchange points within the network, and
- parsing the waybill records so the U.S. portions of waybill record can be routed.

The CCWS have origins, destinations, or transfers that occur within Canada and/or Mexico. Because rail carriers such as CN and CP run between the U.S. and Canada, there is also the

[8] The ID numbering scheme used by the author truncated the names of the FAF region during the calibration phase.

possibility that the waybill will indicate that the train is moving between the U.S. and Canada, where multiple legs are within the United States and/or Canada. Because the railway network is currently only routable for U.S. rail traffic, the waybills containing Canadian and Mexican portions must be truncated to their U.S. portions, with alternate origins and destination nodes substituted to complete the route.

Given the complexity and the various databases involved in this process, Figure 5.10 presents a simplified workflow of the steps for converting the CCWS into routable information for the routing engine.

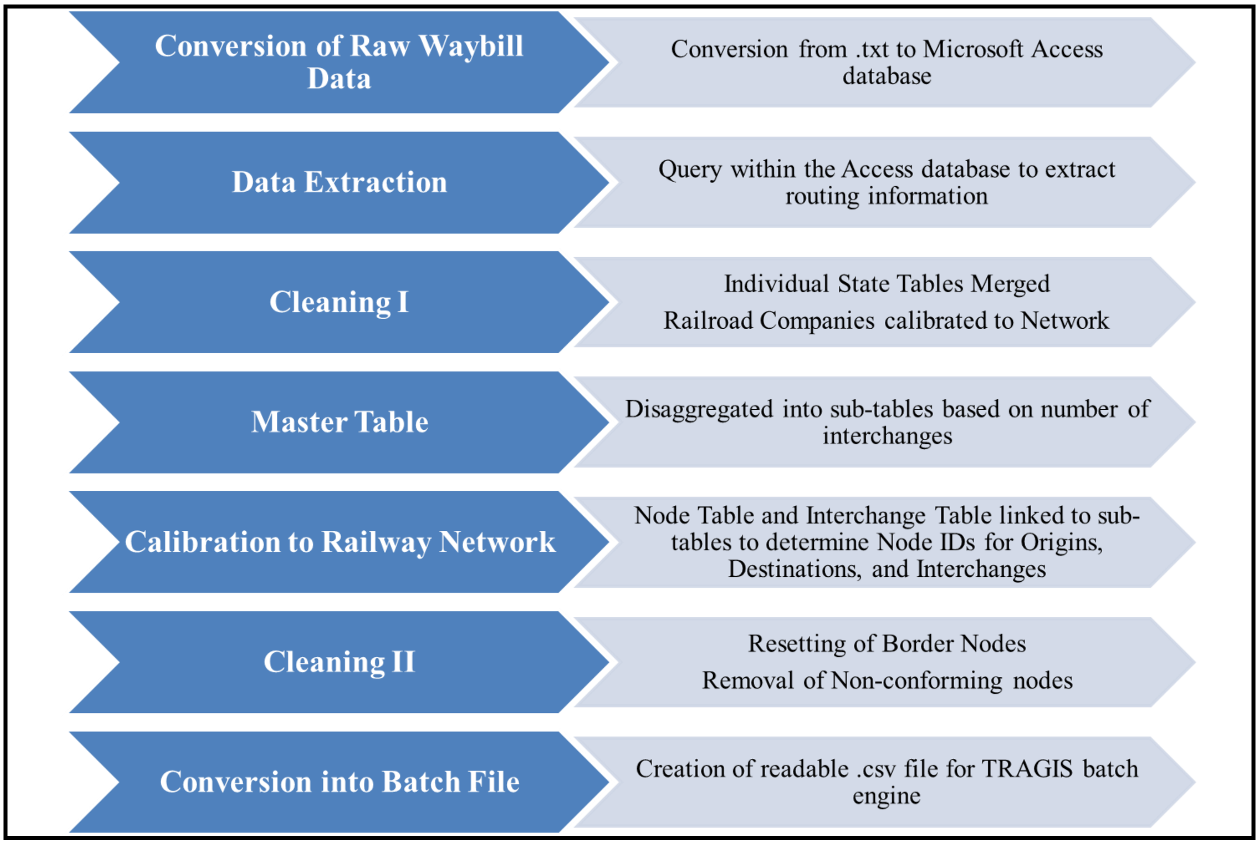

Figure 5.10: Workflow for CCWS Conversion
Credit: M. Fialkoff (2017)

The first step in the process converted the CCWS from its raw form into a usable format. Unlike the FAF that allows users to extract the data either through a tool provided by FHWA or downloading an Access database with all the information preloaded, the CCWS comes as a .TXT file and requires partition of the string of numbers into their respective attributes. Using a reference guide provided by RAILINC (2014), the .TXT file is partitioned and an Access database is created for each year of the CCWS provided. The attributes in the CCWS range from rail carrier information, commodity transported, interchange information, to rate information. For 2011, 2012, and 2013, Table 5.4 summarizes the number of records in each CCWS for those years, respectively. The values provided in Table 5.4 represent 1% - 5% sample of all waybills.

Table 5.4: Waybills Records for Years of Interest

Year	Number of Records
2011	599,588
2012	623,096
2013	641,193

Credit: M. Fialkoff (2017)

Once the database for the base year has been partitioned, the second step is building a series of queries using specific attributes within the CCWS dataset to extract the data needed for calibration with the rail lookup tables developed by ORNL. Table 5.5 provides the attributes used to complete the next step of the process.

Table 5.5: CCWS Attributes used in Railway Network Calibration

Unique Serial Number	Fifth Interchange RR Alpha
Origin Railroad Alpha	Interchange #5 Rule 260
Origin SPLC	Fifth Junction State
First Interchange RR Alpha	Sixth Interchange RR Alpha
Interchange #1 Rule 260	Interchange #6 Rule 260
First Junction State	Sixth Junction State
Second Interchange RR Alpha	Interchange #7 Rule 260
Interchange #2 Rule 260	Seventh Junction State
Second Junction State	Destination SPLC
Third Interchange RR Alpha	Sum of Expanded Carloads
Interchange #3 Rule 260	Sum of Expanded Tonnage
Third Junction State	Sum of Expanded TOFC/COFC Count
Fourth Interchange RR Alpha	State
Interchange #4 Rule 260	
Fourth Junction State	

Credit: M. Fialkoff (2016)

The State field is the critical attribute in the data extraction step. Within the CCWS, each state is its own attribute column and represents whether the train for that particular record passed through the state. If the train traveled through the state, for any portion of the trip, the State field contains the number one; with a number zero, representing that the train did not pass through the state for that waybill sample. The rail study area was defined based on reports discussed in Chapter 2. Those states affected by Hurricane Sandy included: Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania, Virginia, and West Virginia.

Once the individual state queries extracted the waybill samples of interest, the State field was deleted. The individual state data tables formed a Master Table. At this stage, some cleaning was required. First, duplicated records were removed from the Master Table. Second, certain rail companies have different operating names depending on their location (this primarily affects Canadian Rail Companies). In particular, five rail carriers' abbreviations were changed to reflect U.S. operations; these companies are reflected in Table 5.6.

Table 5.6: Rail Abbreviation Corrections

Original Rail Abbreviation	**Reformatted Rail Abbreviation**
CNUS-Canadian National	CN-Canadian National
CPUS-Canadian Pacific	CPRS-Canadian Pacific
KCSM-Kansas City and Southern	KCS-Kansas City and Southern
ST-St. Lawrence and Atlantic	PAS-Pan Am Southern
MMA-Montreal, Maine, and Atlantic	CMQ-Central Maine and Quebec

Credit: S. Peterson (2016)

The final step removes the Unique Serial Number Field and summarizes the Number of Carloads, Number of Tons, and Number of Containers on Flat Cars and Trailers on Flat Cars fields. This step compressed the data. Table 5.7 summarizes the number of individual state records and the number of possible routes after compression.

Table 5.7: Rail Study Area Data Statistics (Mid-Atlantic States)

	2011	**2012**	**2013**
Delaware	6,665	6,848	7,321
District of Columbia	10,914	12,220	12,654
Maryland	40,348	43,114	30,466
New Jersey	35,994	35,629	35,585
New York	38,546	38,692	38,961
Pennsylvania	89,787	92,621	97,216
Virginia	48,012	50,216	37,350
West Virginia	48,585	50,425	38,090
Waybill Sample Size	599,588	623,096	641,193
Number of Possible Routes	**11,356**	**11,025**	**11,027**

Credit: M. Fialkoff (2016)

From the Master table, the next step built a second query to separate the Master Table into sub-tables based on the number of interchanges present in each record. An interchange represents a transfer from one rail carrier to another. Creating these sub-tables supports two goals in this process. First, creating sub-tables based on the number of interchanges creates more manageable and more operable queries when linking the lookup tables to the data. Second, the creation of sub-tables makes it easier to format for the final step, once the calibration is complete. Figure 5.11 shows the sub-table prior to the calibration stage of this process.

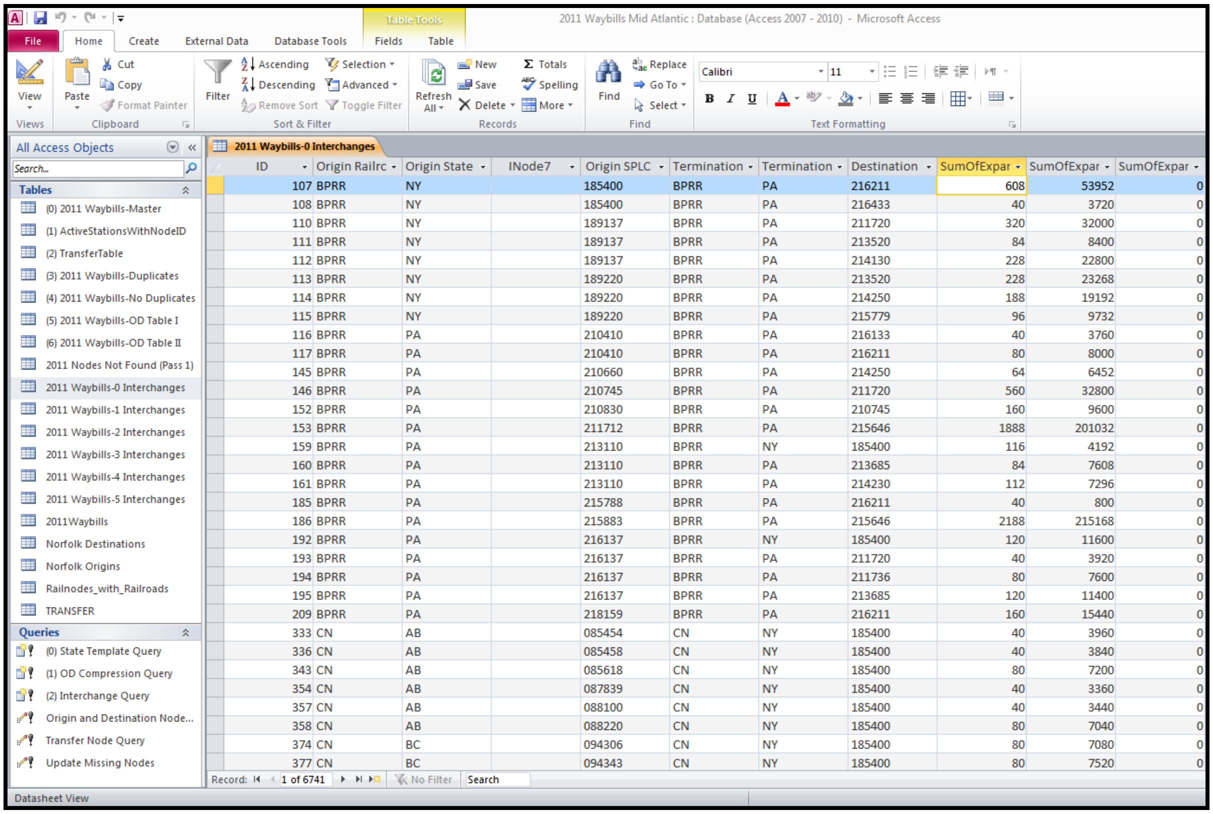

Figure 5.11: Example of Sub-table for Zero Interchanges for CCWS
Credit: M. Fialkoff (2016)

At this stage, the data is ready for calibration with the railway network. As part of the railway network, ORNL has developed a series of lookup tables for the individual nodes in the railway network and a transfer table that indicates which rail company is transferring to what other company at that particular node. For the general node table, the SPLC code discussed earlier becomes extremely important because the SPLC code and the Rail Company at that particular SPLC are the necessary pieces of information needed to link the CCWS to the rail network, particularly when calibrating the origin and destination portion of the waybill record. As part of this lookup table, the Central Station Master Database ensures only Active Stations are used and updates the lookup table with new ownership, trackage, and haulage rights.

Before calibrating to the rail network, each sub-table was inspected for pre-processing issues. In some instances, some routes were removed before calibration because either the routes were un-routable due to inaccurate records or the route was not in the study area. In a few instances, the route was almost completely in Canada, with a slight incursion into the United States, but not enough to trigger a route. Once preprocessing removed the errant routes, the sub-table was ready for calibration with the rail network.

To calibrate the Origin and Destination SPLCs, new columns were added into the sub tables designated ONODE (Origin Node) and DNODE (Destination Node). A query was built linking the Destination SPLC field from the sub-table to the SPLC value in the Active Station Database, which contains the TRAGIS railway node. Figure 5.12 illustrates the linkage between the sub-table and the active station query, which then updates a node value in the respective node field.

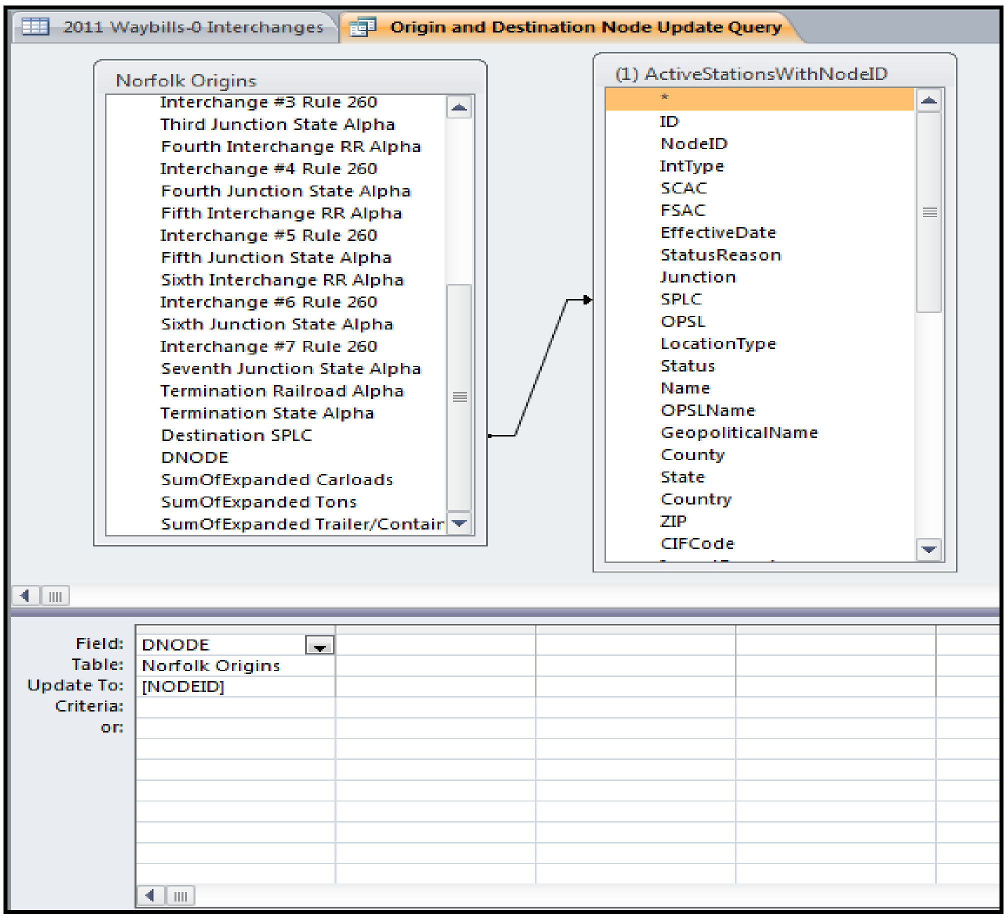

Figure 5.12: Calibration of Origin and Destination Nodes
Credit: M. Fialkoff (2016)

In most cases, this calibration links a majority of the CCWS records to rail nodes. There are a few instances where the calibration does not work and this then requires manual entry. In the case where a domestic SPLC does not link, this requires manual inspection of the network and the node table to find either the node or a node in proximity to the node. In some instances, the missing node has been deactivated since it is no longer active or may substitute to another rail company. For Canadian or Mexican nodes, the Canadian and Mexican portions of the record are removed and "border nodes" are used as the origin or destination node. In this instance, there are only so many international border crossings that the Class I carriers use, and based on the last foreign SPLC before entry into the U.S., one can infer the entry or exit point. For example, rail carriers CN and CSX moving through Quebec have limited border crossings; either they will enter the U.S. at Fort Covington in New York or East Alsburgh, Vermont. By also looking at the destination of the train, one can then determine the entry node. This requires manual entry of the origin/destination node.

Once calibrated, the next step is calibrating the transfer positions, also known as the interchanges. To prepare the sub-table, new columns are added that contain the Interchange Nodes once they are linked. In this step, another query is constructed that looks at the first rail company (the company that is handing off the freight), the abbreviation used to designate the transfer node, and the second rail carrier (the carrier picking up the freight to continue the route). Figure 5.13 illustrates the query used to calibrate the transfer data from CCWS into a transfer node. This step uses the Transfer Lookup Table and not the General Node table. The Transfer Lookup Table does not use the SPLC Code, but rather uses a five-letter abbreviation for the transfer point.

With the transfer node calibration, there is a higher chance that the node will not populate the field. This happens for a variety of reasons. First, especially with the Canadian-U.S. rail movements, the rail carriers are starting in the United States, traversing into Canada, re-entering the United States, and ending in the United States. To remedy this problem, those routes were individually examined to determine their movement within the study area. These routes were spliced so the part of the route that was within the study area was used. This also happened with Mexico, but the occurrences were lower and the remedies were to default the rail carrier to the border rail carrier (there was no Mexico-US-Mexico routes).

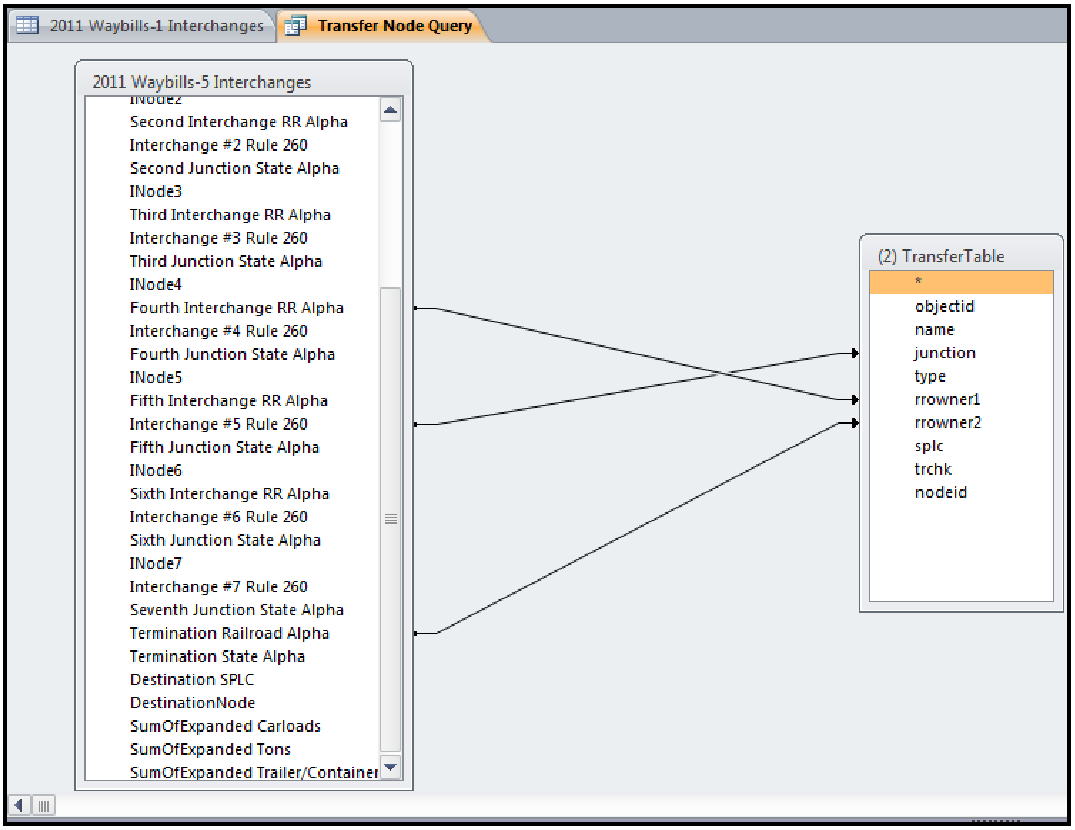

Figure 5.13: Interchange Node Query
Credit: M. Fialkoff (2016)

A more problematic issue occurred when a domestic transfer position was missing. In these instances, there are two options to fix this issue. The first is to remove the transfer, allow the routing algorithm to path find for itself, and find its own transfer point. The second is using subject matter expertise to force a transfer at a specific node. An example of this occurs in major cities that connect eastern rail carriers, CSX and NS, to western carriers, BNSF and UP, and the Canadian railroads CN and CP. For this research, errant transfer nodes were removed and the algorithm generated the most efficient route, finding its own transfer node. These "special nodes" are discussed further in Section 5.4.2.1.

After each sub-table linked to the rail network, the sub-tables were cleaned of non-conforming transfer nodes and formatted for the batch process. Whereas the WebTRAGIS GUI allows drop-down windows to find nodes, the batch process uses the Node ID numbers instead of the node name to generate the route. The batch process requires a particular order with respect to the Node ID, rail company abbreviation, and transfer nodes so the routing engine can properly read each line of the file. As Table 5.8 shows, each route must also indicate which mode of transportation is used. This instructs the routing engine whether to use the highway algorithm or the railway algorithm.

Once the sub-tables merged and formatted into the batch process format, the table was converted into .CSV format. Prior to running the routes and generating shapefiles, the file was checked to determine if the routes would be generated. This process checked the .CSV file against the network to determine if generation was feasible. Once this process was complete, a diagnostic report showed which nodes/rail company pairs could not be found and how many routes were affected because of this. After this check, an update query corrected any errors and the diagnostic report checked the .CSV batch file again. Once cleared, the routing algorithm generated shapefiles for each route and a network-wide shapefile showing the aggregate volumes of each route in one shapefile.

Table 5.8: TRAGIS Batch Format for Rail

Attribute	Explanation	Attribute	Explanation
RouteID		TRF5Node	Transfer 5 Node ID
RouteName	Left Blank	TRF5RR	Transfer 5 RR Company
Mode	Rail	TRF6Node	Transfer 6 Node ID
ONODEID	Origin Node ID	TRF6RR	Transfer 6 RR Company
OCompany	Originating Rail Company	DNODEID	Destination Node ID
TRF1Node	Transfer 1 Node ID	DCompany	Destination Rail Company
TRF1RR	Transfer 1 RR Company	Carloads	Number of Carloads
TRF2Node	Transfer 2 Node ID	Tons	Tons carried by the train
TRF2RR	Transfer 2 RR Company	Trailer/Containers	Number of Containers
TRF3Node	Transfer 3 Node ID		
TRF3RR	Transfer 3 RR Company		
TRF4Node	Transfer 4 Node ID		
TRF4RR	Transfer 4 RR Company		

Credit: M. Fialkoff (2016)

5.4.2.1 Special Transfer Nodes

Although the decision to remove unmatched transfer nodes and allow the algorithm to path find independent of the transfer nodes, it is important to explain the challenge associated with the transfer nodes. In contrast to other transfer points, Chicago and East St. Louis are gateways for transcontinental rail transportation. In these cities, western rail carriers such as BNSF and UP link with eastern rail carriers CSX and NS to hand off freight from one carrier to another. These hand-offs can occur either by the Class I carriers uncoupling their locomotives from the freight train and hooking up the new carrier's locomotives. In most instances, an intermediary short line or shuttle service moves the freight train across the city from one location to another. In Chicago, the Belt Railway Company (BRC) and in East St. Louis, the Terminal Railroad Association of St. Louis (TRRA) acts as the shuttle.

Because the CCWS is an economic dataset, reflecting billing information and not routing information, the records generically identify transfers in these cities broadly, using abbreviations such as CHGO to indicate a Chicago transfer and ESTL to indicate a transfer in East St. Louis. In contrast to the waybill data, the rail network developed by ORNL contains more information for these cities, with greater information on the companies having ownership rights. While the ORNL transfer table has accounted for numerous transfers within these cities, some transfer combinations between rail carriers are difficult to identify. Where a transfer is not on the Transfer Lookup table, there will be no corresponding node. To highlight this point, Figure 5.14 illustrates the railway network within the Chicago city boundary and shows the various potential transfer points.

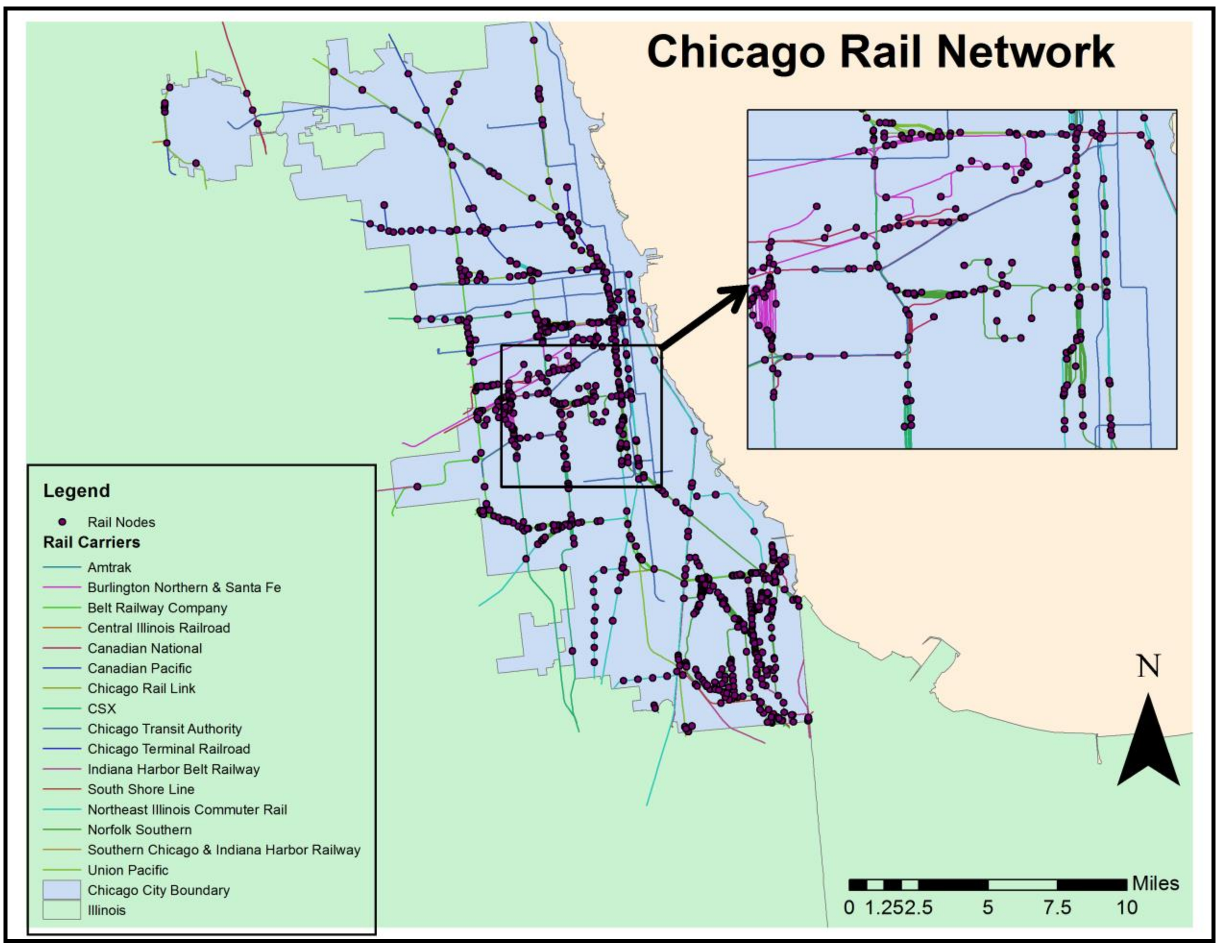

Figure 5.14: Chicago Rail Network
Credit: M. Fialkoff (2017)

In addition to the Class I carriers, the network also contains the commuter lines and the short lines that act as shuttle service for Class I carriers that might not have interlining agreements. In short, with close to nine-hundred links, representing sixteen rail carriers, the detail of the rail network dwarfs the broad description of CHGO as ascribed on the waybills.

5.5 Validation Analysis for TRAGIS Generated Routes

In the previous sections, the emphasis was on the modeling algorithm, computational implementation, and data calibration of the transportation networks used in WebTRAGIS and the FAF and CCWS. In addition to generating the routes for analysis, a validation analysis compares the predicted routes generated by the TRAGIS routing algorithms to routes generated by independent transportation routing databases. This section discusses the methodology involved in conducting the validation analysis and introduces the Relative Root Mean Square Error (RRMSE) value as a statistical measure to compare individual route performance and the overall sample of routes selected for analysis in both the highway and railway contexts.

The protocol used for the validation analysis in this dissertation will follow the same procedure established by Maheras and Pippen (1995) when they conducted a similar analysis for the routing algorithms in HIGHWAY and INTERLINE. Prior to conducting the analysis, Maheras and Pippen (1995) explained that the concept of validation analysis is based on computer software analysis, with the core purpose being to make sure that the software system is complying with its original purpose. The validation analysis acts as a check to ensure that the software is doing what it is supposed to be doing. With respect to WebTRAGIS and its routing algorithms, validation analysis compares the distances of the routes generated by WebTRAGIS (the predicted distance) against independent routing programs for highway and railway routes (the observed distance). When comparing the predicted distance to the observed distance, if the difference between the two values is small (within the acceptance criterion established for the validation analysis), then the predictions are considered to be valid, or representing accurate route generation.

A quantitative measure compares the difference between the predicted routes generated by WebTRAGIS and the observed routes generated by the independent databases. Building on work by Baca and Magnuson (1990), the report authored by Maheras and Pippen (1995) determined a variety of statistical metrics exist to compare the predicted routes against the observed routes. These measures include the maximum distance between the two values, the maximum relative difference between the two values, and the Relative Root Mean Square Error (RRMSE). In contrast to the other two measures, the RRMSE allows for an overall measure of a number of routes with a value generated that can be categorized based on pre-determined acceptance criteria.

Previous validation analysis tried different statistical measures to assess the validity of the routes generated. For the validation analysis of HIGHWAY and INTERLINE, Maheras and Pippen (1995) tried three metrics: (1) the difference between the predicted and observed routes, (2) the absolute value of the percent difference between the predicted and observed routes, and (3), the RRMSE. The statistical measures used the formulas expressed in Equations 5-4, 5-5, and 5-6:

$$Absolute\ \ Difference = P_i - O_i \qquad \textbf{(5-4)}$$

$$Percent\ \ Difference = \frac{P_i - O_i}{P_i} \times 100 \qquad \textbf{(5-5)}$$

$$RRMSE = \sqrt{\frac{\sum_{i=1}^{k}\left(\frac{P_i - O_i}{P_i}\right)^2}{k}} \qquad \textbf{(5-6)}$$

where

P_i	=	the predicted distance for route *i;*
O_i	=	the observed distance for route *i;*
RRMSE	=	Relative Root Mean Square Error;
k	=	the number of routes evaluated sampled.

The acceptance criterion used in this analysis reflects the same criterion used by Maheras and Pippen (1995). Because the routing algorithms of WebTRAGIS have not changed significantly since the 1995 analysis, the acceptance criterion remains the same. As Maheras and Pippen explained, the values for the analysis based on RRMSE were derived by Baca and Magnuson (1990) and are referenced in Table 5.9.

Table 5.9: Acceptance Criterion Values for RRMSE Analysis

Condition	Criterion Range
Excellent	RRMSE ≤ 0.05
Acceptable	0.05 < RRMSE ≤ 0.10
Unacceptable	RRMSE > 0.10

Source: Baca and Magnuson (1990)

Similar to the Maheras and Pippen (1995) report, the number of routes generated in this study was substantial. For the highway routes, TRAGIS generated 757 highway routes for each of the three scenarios. For the railway routes, across three years of the CCWS used, TRAGIS generated between ten-thousand and eleven-thousand routes. For both the highway and railway analysis, the number of routes to validate make it impractical to conduct the validation analysis because some distances would be duplicated and skew the RRMSE values. To develop a manageable sample size, a centralization approach was used. Under this approach, an origin was used and number of routes originating from that location comprised the sample size for the analysis, with the origin being the centralization point. Because the Port of Norfolk was the location where cargo diverted to, the Norfolk International Terminal node for both the highway and railway networks was used as the centralization point. In the case of the railway, Norfolk Southern was the originating rail company selected.

For the observed routes, three independent databases were used to generate distances for the observed routes portion of the analysis. For the highway routes, Google Maps generated the observed routes and respective distances. Originally, the observed railway route distance was extracted from the Total Distance field within the CCWS. According to RAILINC's 2013 STB CCWS Reference Guide, Total Distance is defined as a five-digit numeric value that is an aggregate calculation of all the carriers' distances for a particular waybill record. The distances were calculated using the Princeton Transportation Network Model (PTNM), which ALK Technologies developed. One problem with using the PTNM is limited documentation that exists for understanding how PTNM works and how the distances were arrived at using that particular model. The most recent documentation to date is from 2003 (ALKFLOW, 2003).

In reviewing the rail carriers that ran out of NIT, Norfolk Southern (NS) is the primary carrier servicing NIT. While the Total Distance field from the CCWS provided a reference, NS supplied internal data on the origin-destination pairs where NIT was the origin (LoSapio, 2016). Using PC Miler Rail v. 22.0.140.0, the NIT origin-destination pairs were sent to Norfolk Southern and they in turn used PC Miler to generate observed route distances using similar parameters as entered into WebTRAGIS. Chapter 6 further discusses the results from the validation analysis on individual routes selected and for a selection of routes selected from the batches generated for the analysis.

5.6 Summary

In this chapter, the emphasis focused on why WebTRAGIS was used for this research. The chapter chronicled the evolution of the program and its legacy systems of HIGHWAY and INTERLINE. The chapter also explained that although the original purpose for WebTRAGIS was for route analysis of SNF and HLRW, the platform is versatile in its application for studying freight diversion. In addition to the program itself, the chapter outlined the procedures used to integrate transportation datasets such as the Freight Analysis Framework and the Confidential Carload Waybill Sample in such a manner that economic data that is not geo-spatially explicit can be routed using the routing engines within the WebTRAGIS program. Through this process, the visualization of these datasets provides the opportunity to study the effect of increased traffic emanating from Norfolk because of the closure of the Port of New York and New Jersey. More importantly, the implementation of datasets like FAF and CCWS in platforms like WebTRAGIS provides decision-makers with the ability to study policy interventions, such as the Jones Act and its impact on transportation networks.

5.7 References

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Chapter 6: Results and Analysis

6.1 Introduction

Chapters 4 and 5 introduced the datasets and networks used for this research. Applying the System of Systems developed throughout the dissertation so far, Chapter 6 focuses on the Jones Act and its impact on the transportation system it governs. Revisiting the System of Systems framework discussed previously, Figure 6.1 illustrates the focus of this chapter, with the transportation system and the Jones Act elements of the System of Systems framework emphasized.

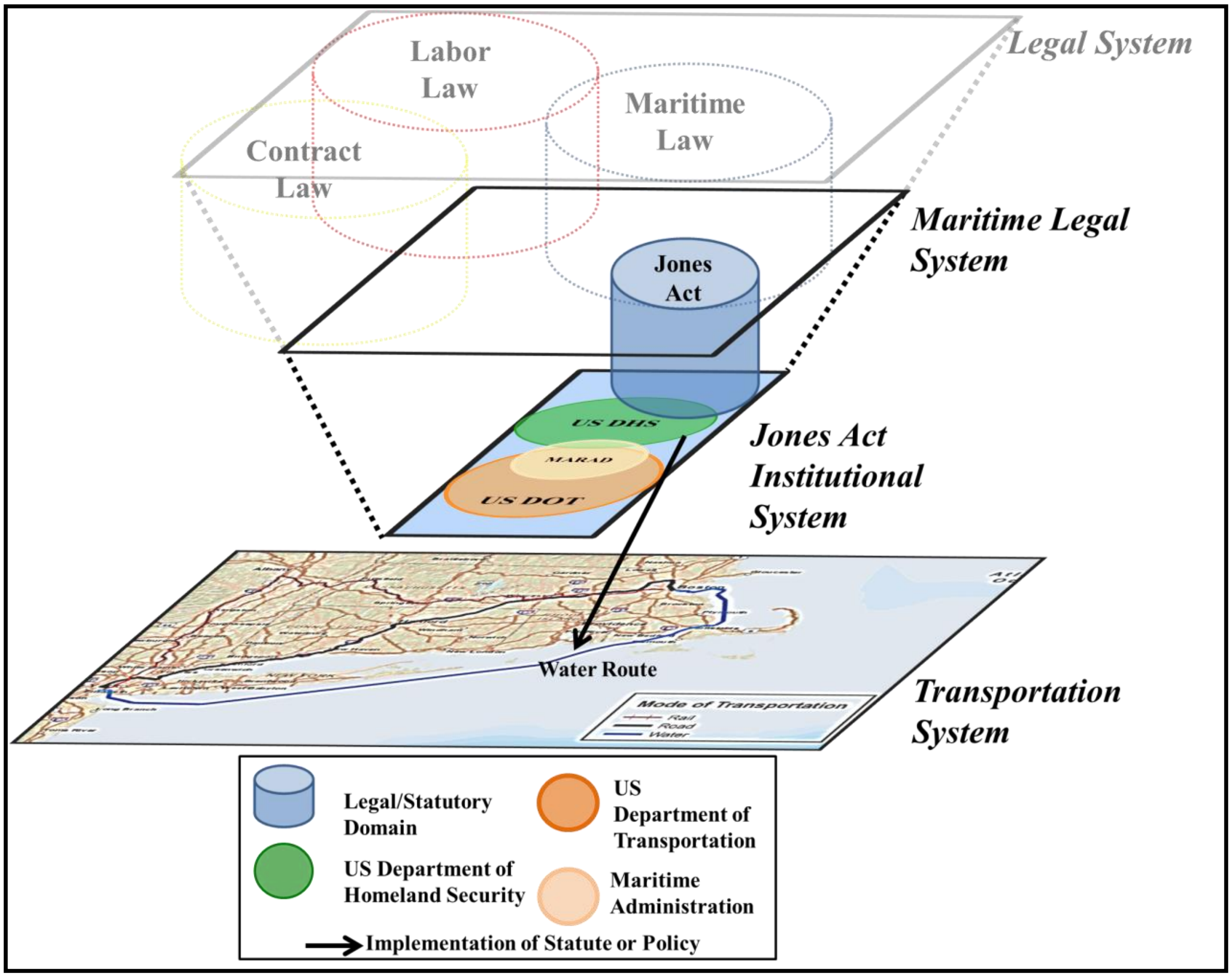

Figure 6.1: System of Systems Framework Revisited
Credit: M. Fialkoff (2017)

The previous chapter focused on tools for analyzing the relationship between the maritime legal system (in this case, the Jones Act) and transportation system. For this research WebTRAGIS provided a platform to study how changes in a law such as the Jones Act affects freight movement and how its functionality as a transportation routing tool can be used to study the network and policy effects of freight disruption. Specifically, Chapter 5 laid out the methodology used to convert transportation data into routable data.

Starting with the implementation methodologies discussed in Chapter 5, the first part of this chapter reports the results of calibration of the FAF and the CCWS to the highway and railway networks, respectively. From there, this chapter focuses on reporting the results from the individual scenarios and the validation analysis for the highway and railway routes generated by TRAGIS.

6.2 Summary Results for WebTRAGIS Route Generation[9]

Chapter 5 explained the process for converting transportation data that lacks geo-spatial reference to routable information for use in the TRAGIS routing engine for route generation. This dissertation used the Freight Analysis Framework (FAF) and the Confidential Carload Waybill Sample (CCWS) for this process. The following sections report the conversion efforts for both the FAF and the CCWS.

6.2.1 Highway Summary Results

The highway study area discussed in Chapter 5 consisted of 23 regions and 5 exterior regions representing five exterior regions that are major freight generating areas. After establishing the number of zones and obtaining the zone-to-zone freight movements from the FAF dataset, the freight tonnages were converted to trucks using the process described in Section 4.6.1.1 of Chapter 4. From this data, WebTRAGIS generated 757 routes based on the origin and destination from the regions used. Table 6.1 reports the results of the route generation, reporting the number of possible routes generated and the number of routes actually generated.

Table 6.1: Highway Route Generation Statistics

Number of Interior Centroids (*a*)	23
Number of Exterior Centroids (*b*)	5
Total Number of Nodes (*a* + *b*)	28
Number of Proposed Routes (pre-processing)	757
Number of Routes Generated	757
Final % Capture	100

Credit: M. Fialkoff (2017)

[9] This research was done utilizing the WebTRAGIS routing analysis system developed by UT-Battelle, LLC, operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy. The United States Government has certain rights in any generated routing data. Neither UT-Battelle, LLC nor the United States Department of Energy, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability of responsibility for the accuracy, completeness, or usefulness of the data generated.

The last row in Table 6.1 reports a final percent capture value. This value represents the number of proposed routes compared to the number of routes generated by the routing engine. This final percent capture value describes the number of route shapefiles generated.

The highway algorithm and routing procedure is based on the shortest path solution, where the objective function of the algorithm is to generate routes with lowest impedance value based on the constraints within the objective function. In the context of traffic assignment, traditional assignment techniques are based on equilibrium models that try to account for the fact that travelers may not have complete information concerning the congestion on their planned route (Battelle, 2011). Traditional assignment techniques such as the Stochastic User Equilibrium (SUE) try to account for this incomplete information.

Note that traffic assignment using the shortest path solution or simple implementations such as the algorithms used in TRAGIS do not reflect "normal" traffic assignment, but are applicable in diversion analysis. Under disruptive situations, simple assignment of freight using shortest path solution algorithms are an acceptable alternative to more traditional traffic assignment models (Georgia Tech Research Corporation *et al.* 2012). The assumption for a shortest path assignment in these situations is that customers want to get their diverted freight as fast as possible (Georgia Tech Research Corporation *et al.* 2012). In *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System*, the authors differentiated the network implications, including the assignment methodology with the economic and downstream supply chain costs (Georgia Tech Research Corporation *et al.* 2012). In network studies, economic impacts of disruptions are not considered (Georgia Tech Research Corporation *et al.* 2012).

6.2.2 Railway Summary Results

Based on the data within the CCWS, TRAGIS generated more routes than in the highway portion of this research. In contrast to the FAF that uses zone-to-zone movement, the data structure for the CCWS required a step-wise process to extract the rail data of interest. For the rail data extraction, eight states representing the Mid-Atlantic region of the United States were selected. After linking the CCWS data to the ORNL railway network, the data was formatted into the batch process file and subsequently processed in TRAGIS. Table 6.2 reports the results of the batch process across the three years of the CCWS used in this research.

Table 6.2: Railway Route Generation Statistics

	Confidential Carload Waybill Sample Year		
	2011	**2012**	**2013**
Number of Records in Original Waybill Sample	599,588	623,096	641,193
Initial Sample Post Compression	11,356	11,025	11,027
Pre-processing Route Removal	5	0	3
Pre-processing Possible Routes (*a*)	11,351	11,025	11,024
% Eligible Routes after Pre-processing	99.96	100.00	99.97
Number of Error Nodes (Based on Diagnostic Report)	36	49	57
Number of Error Routes resulting from Error Nodes (Based on Diagnostic Report)	185	169	199
Number of Error Routes (Based on Final Output)	105	87	105
Number of Routes Generated (*b*)	11,246	10,938	10,919
Final % Capture (*b/a* x 100)	99.07	99.21	99.05

Credit: M. Fialkoff (2017)

Within Table 6.2, there are two results that require a brief explanation. First, for years 2011 and 2013, five and three routes respectively were removed from the possible routes prior to processing through TRAGIS. These pre-process route removals were necessary because these routes either were purely Canadian routes or when calibrated to the rail network, became unroutable. While all efforts were made to capture these routes, some routes failed to calibrate to the railroad network. Even with these preliminary route exclusions, the linkage resulted in initial percentages of eligible routes is above 99% with 2012 reporting 100% initial calibration.

Of interest within the results in Table 6.2 is the number of errors nodes, the number of error routes per the Diagnostic Report, and the actual number of error routes generated. In theory, the number of error routes reported on the Diagnostic Report should equal the number of actual error routes that are present after processing the batch file. Per Table 6.2, there is approximately a 50% reduction in number of actual error routes as compared to the number of error routes. The difference in values occurred because of the logic within the routing engine. When the program reads the route in the batch file, it makes sure the railway network is connected such that a route is possible, but then inspects whether the nodes used to form the route (origin, interchange, and destination) are correctly linked. If there is a node mismatch (either the node does not exist in the network anymore or the rail carrier attached to the node is incorrect), the routing engine will indicate an error. Where there is no interchange node, the

Diagnostic Report will indicate a node error and the route fails. However, when an interchange node is present, depending on the node in error, the routing engine will create a route based off the nodes that create a route. To illustrate this, Figure 6.2 represents four possible route generation options with respect to rail routing in TRAGIS.

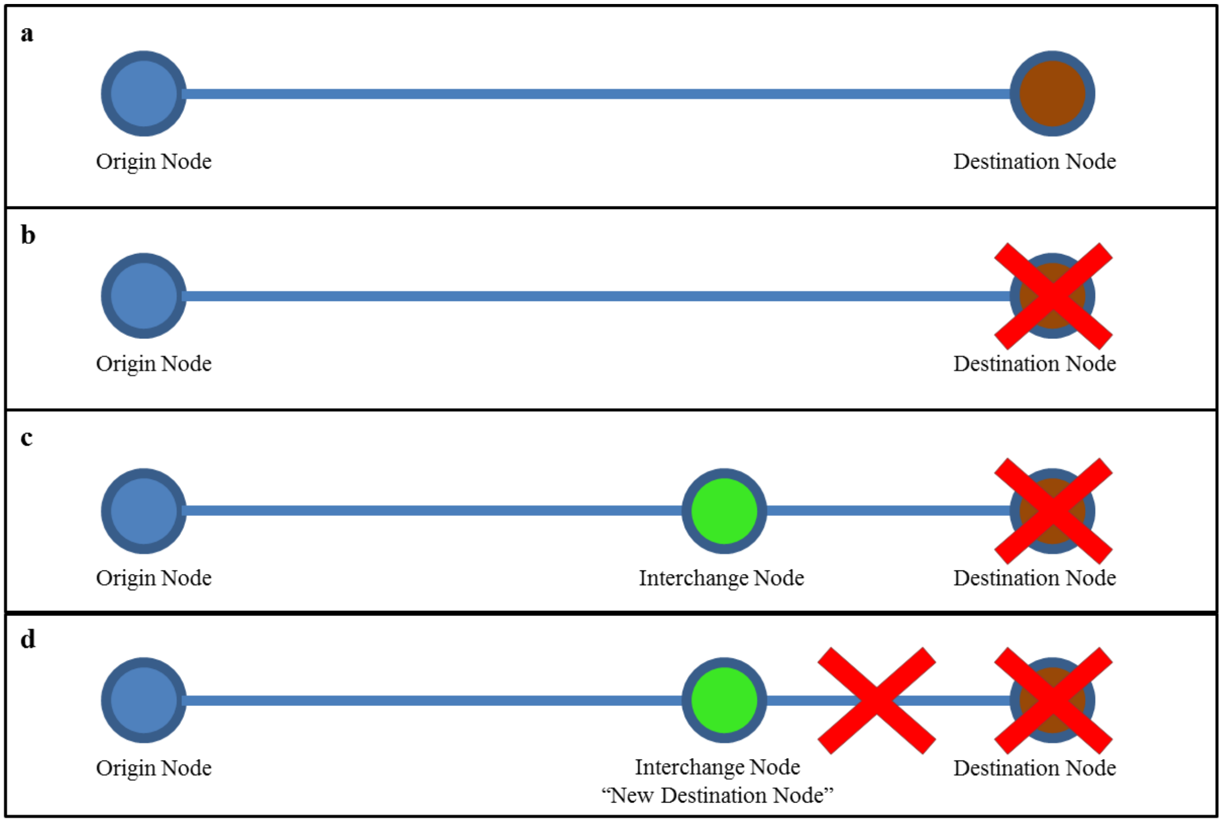

Figure 6.2: Routing Logic for Error Railway Nodes
Credit: M. Fialkoff (2017)

In Figure 6.2(a), a hypothetical route is presented with an origin and destination. In (a), the origin and destination nodes are properly linked to the network and the routing engine generates a route and an appropriate shapefile. In Figure 6.2(b), the destination node is not properly linked. In this case, the routing engine will detect the node in error, report the incorrect node, and the route will fail, with no shapefile generation and a comment in the Diagnostic Report indicating the RouteID number. In (c), an origin, interchange node, and destination node are present, with the destination node being improperly oriented. In that case, if the interchange node is properly linked, the interchange node replaces the errant destination node and becomes the new destination node. As represented in (d), this means that the leg between the new destination node and the errant destination node will not be generated since the original destination is incorrect and no route can be generated.

For the final percent capture, the number represents the number of routes generated by the routing engine, including the creating of "partial routes" because of errant nodes. The routing engine generated approximately 99% of the routes in the batch process, even after post processing and review of the errant nodes. While an intermediate post-process step repaired the initial results as described in Chapter 5, the final percent capture values indicate that the conversion process for the railway network yields acceptable calibration of the data to the railway network.

6.3 Results from Scenarios

In Chapter 4, three scenarios were developed to measure the effect of the Jones Act on freight movement. The three scenarios are as follows:

- **Scenario 1**: Baseline Freight Movement- Normal Operations;
- **Scenario 2**: Hurricane Sandy Conditions- Jones Act in Place; and
- **Scenario 3**: Hurricane Sandy Conditions- Jones Act Relaxed

The following sections report the results for the various scenarios developed in line with the research question; specifically, what effect does the Jones Act restriction have on freight transportation movement in the aftermath of a disruptive event, in this case, Hurricane Sandy.

6.3.1 Scenario 1: Baseline Freight Movement-Normal Operations

This scenario represents "normal" freight operations, with preparation and representation of the FAF and CCWS following the conversion and calibration procedures described in Chapter 4 and Chapter 5. This scenario represents the base case or the control to compare freight movements in Scenarios 2 and 3.

6.3.1.1 Daily Truck Counts for Study Area

Following the conversion of freight flow to daily truck counts, Figure 6.3 illustrates the daily truck counts for the highway study. According to Figure 6.3, the I-95 Corridor from Northern New Jersey to Central New Jersey has the highest truck counts. Along this section of I-95, approximately 12,000 trucks travel per day. When I-95 intersects Interstate 276 (Pennsylvania Turnpike) around Exit 6, the truck traffic along I-95 decreases to similar levels to that on the Pennsylvania Turnpike. The truck count along I-95 continues to be high between Philadelphia and Richmond, Virginia, with a subsequent decrease in truck traffic for points south of Richmond.

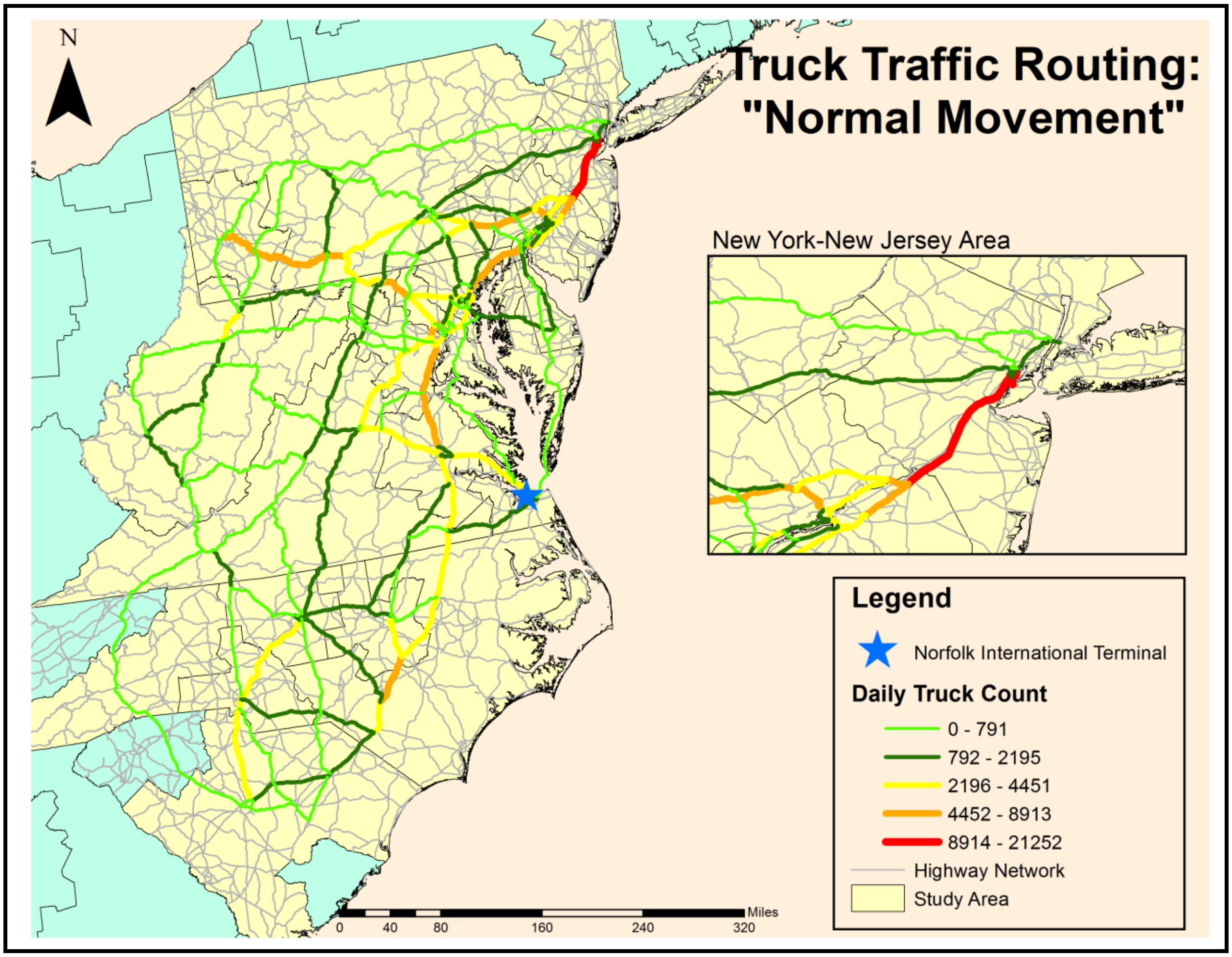

Figure 6.3: Daily Truck Counts for Study Area under Normal Conditions
Credit: M. Fialkoff (2017)

When comparing the truck counts along major Interstates, there is a major difference in truck counts between I-95 and I-81. The results in Figure 6.3 highlight that truck traffic along I-95 can be as low as 700 trucks to as high as 15,000 trucks per day. In contrast, Figure 6.3 indicates that I-81 does not have high daily truck traffic. Per the Virginia Department of Transportation (VDOT), I-81 sees truck counts ranging from 9,180 to 13,480 (VDOT, n.d.). This difference in truck counts between what VDOT reported and what Figure 6.3 reports is because of the assignment methodology used. In this work, the assignment methodology follows a shortest path assignment in comparison to the traditional Stochastic User Equilibrium (SUE) assignment (Battelle, 2011). This difference in assignment methodology was discussed in the context of Interstate 5 in Los Angeles County, California (Battelle, 2011). Using an All or Nothing (AON) approach, most freight traffic traveled on I-5, but the authors noted that most freight travels on U.S. Highway 99. The question of assignment methodology has been addressed by Schulz (2012) and Georgia Tech Research Corporation *et al.* (2012). In both reports, the authors conclude that the shortest path solution is a viable assignment method given the desire of the customer to get their goods as fast as possible (Georgia Tech Research Corporation *et al.* 2012; Schulz, 2012).

An area of interest for this study is around the Norfolk International Terminal (NIT). Figure 6.4 represents the major roads in the immediate vicinity of Norfolk and NIT. Figure 6.5 shows that Terminal Road, the main access road for trucks entering and exiting NIT, approximately 4,900 trucks travel everyday under normal conditions. When Terminal Road connects with the Hampton Road Beltway (Interstate 64), the truck traffic splits between two different paths; approximately 3,400 trucks per day head north to the Hampton Roads Bridge-Tunnel, with the remaining 1,500 trucks traveling westward on Interstate 64.

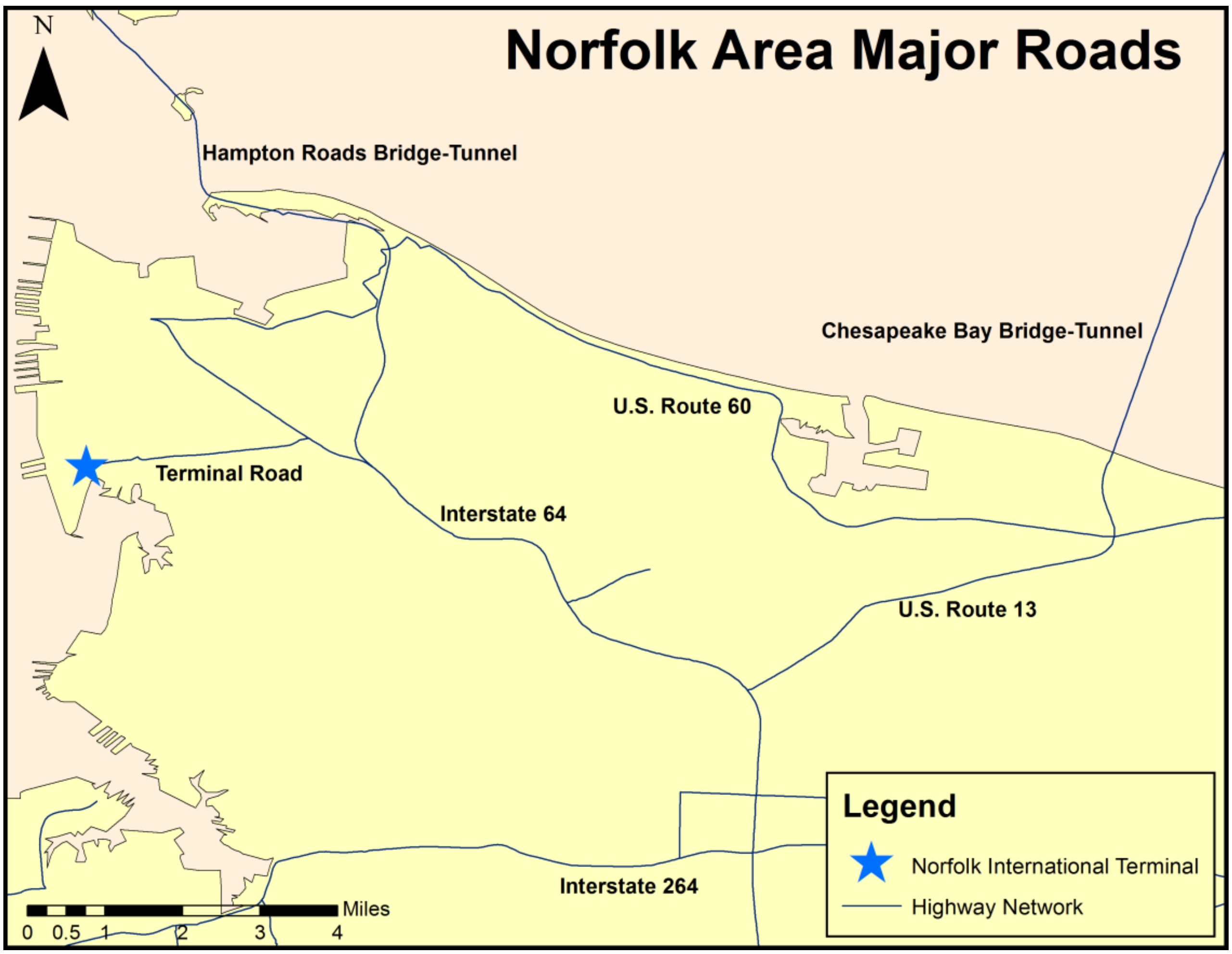

Figure 6.4: Norfolk Area Major Roads
Credit: M. Fialkoff (2017)

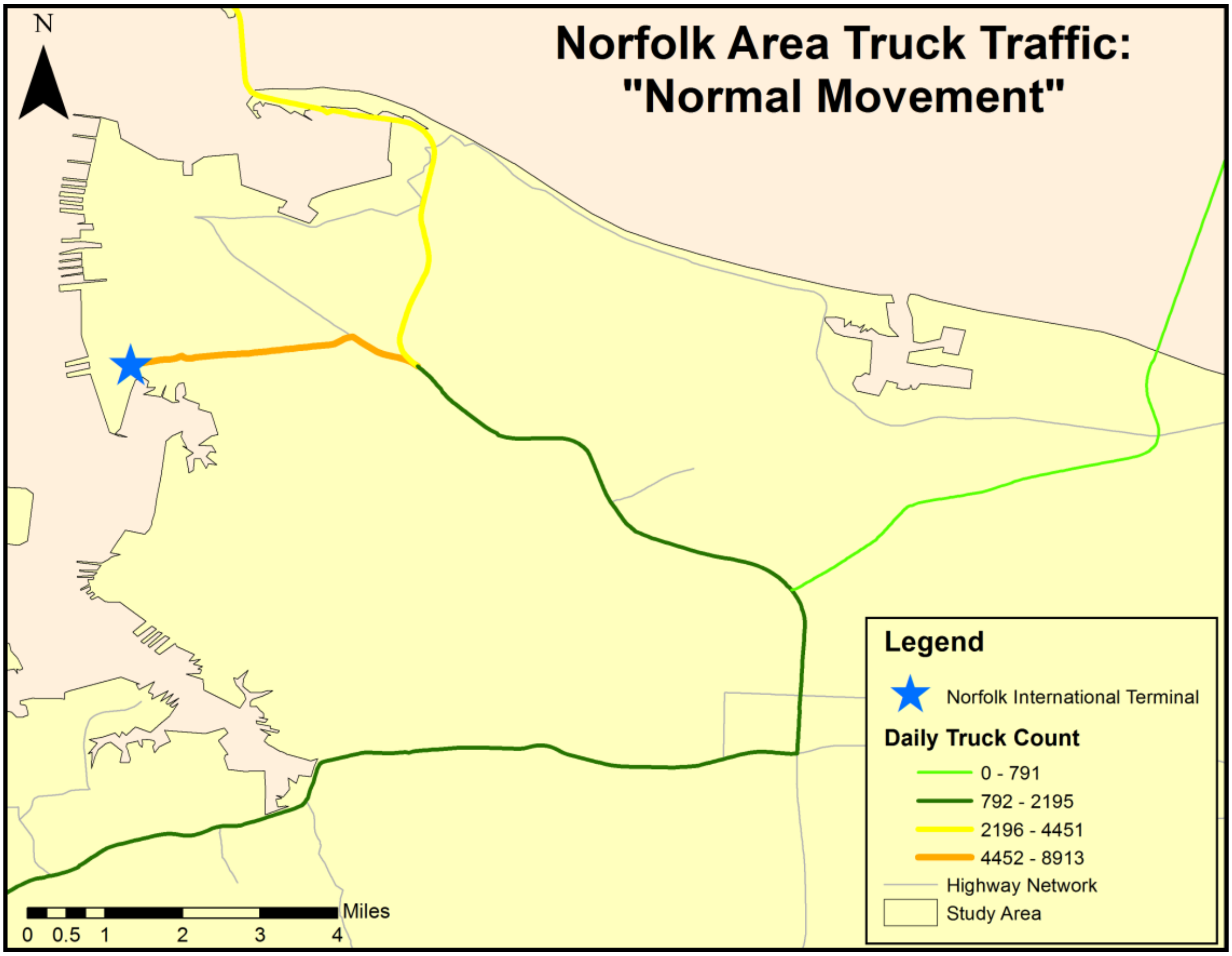

Figure 6.5: Norfolk Area Truck Traffic under Normal Conditions
Credit: M. Fialkoff (2017)

6.3.1.2 Rail Traffic Analysis under Normal Operations

Figure 6.6 represents the daily rail traffic for the waybills flowed over the ORNL railway network. In the absence of railroad timetable information, capacity values for the network were calculated using the theoretical zero-delay capacity analysis described by Tolliver (2005).

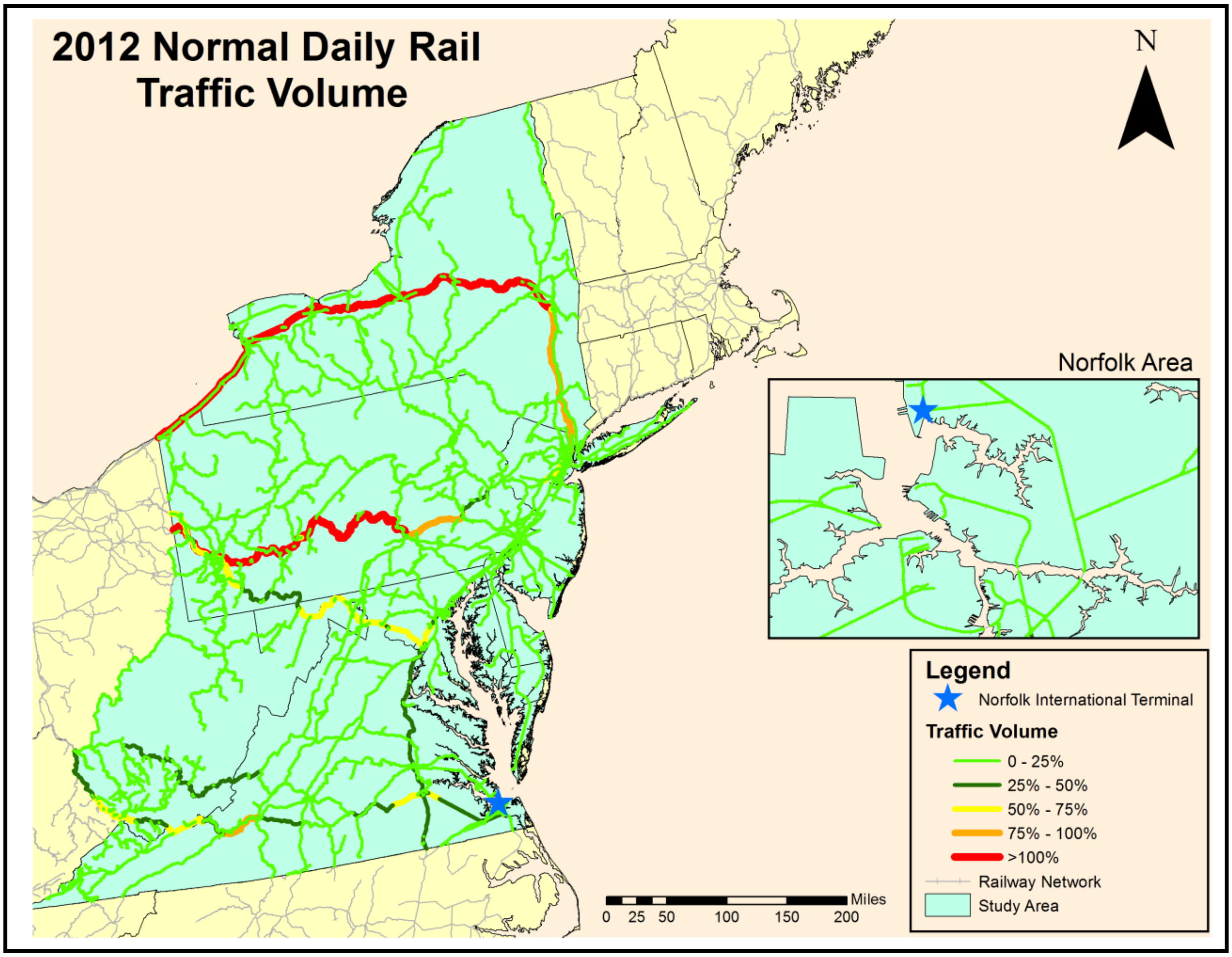

Figure 6.6: Daily Rail Traffic Volumes
Credit: M. Fialkoff (2017)

The traffic values are a resultant of a ratio of daily train volumes to the practical line capacity as calculated using the method described in Chapter 4. Within the Mid-Atlantic States, two corridors show high traffic; in New York, the Albany Division of CSX Transportation and in Central Pennsylvania, the Harrisburg, and Pittsburgh Divisions of Norfolk Southern. Other portions of the network which are at 75% traffic include the North-South portion of the Albany Division in New York (this portion of the network parallels the Hudson River) and portions of the Harrisburg Division in Pennsylvania (between Lebanon and Harrisburg) (Norfolk Southern, 2015). Surrounding the Norfolk International Terminal (NIT), Norfolk Southern is the predominant rail carrier, with the Norfolk and Portsmouth Belt Line Railroad (NPBL) and CSX having a trackage right and a haulage right, respectively. Figure 6.6 shows low traffic volumes in the immediate vicinity of NIT.

When considering the results illustrated in Figure 6.6, it is important to acknowledge that the traffic volumes represented are calculated solely on the CCWS records. Previous analysis using the ORNL railway network focused on the impact of Amtrak on-time performance and how Amtrak caused bottlenecks for the Class I railroads (Krier *et al.*2014). Also of note is that within the Northeast Corridor, the results above do not account for local commuter traffic such as Metro-North, PATH, Southeastern Pennsylvania Transportation Authority (SEPTA), or MARC (Maryland Transportation Authority). These commuter lines add traffic not reported in this research. However, the information in the CCWS provide sufficient information to study the freight rail impacts of diverting freight from one part of the network to another portion of the network to understand resulting impacts

6.3.2 Scenario 2: Hurricane Sandy Conditions-Jones Act in Place

In this scenario, an additional 6,500 units (containers) are loaded as network traffic for both the highway and railway networks. Using distribution of freight for each mode that leaves NIT, the network was loaded accordingly to represent increased truck traffic and rail traffic leaving from NIT because of the Port of New York and New Jersey suspending traffic. This scenario represents how freight was moving through the freight network in the aftermath of Hurricane Sandy, with the Jones Act still in place. With the Jones Act restriction in place, foreign vessels could not move between Norfolk, New York, or other Ports as this would be a violation of the Statute.

6.3.2.1 Daily Truck Counts for Study Area

Of the 6,500 containers diverted to NIT, approximately 4,400 left NIT via truck or railroad, with the remaining 2,100 being barged out of NIT. From the remaining 4,400 containers traveling by land-based transportation modes, 2,816 traveled by truck on the highway network. Although containers left NIT via barge, the Jones Act remained in place. As illustrated in Figure 6.7, the additional truck traffic does not change the daily truck traffic counts for those roads traveled within the study area.

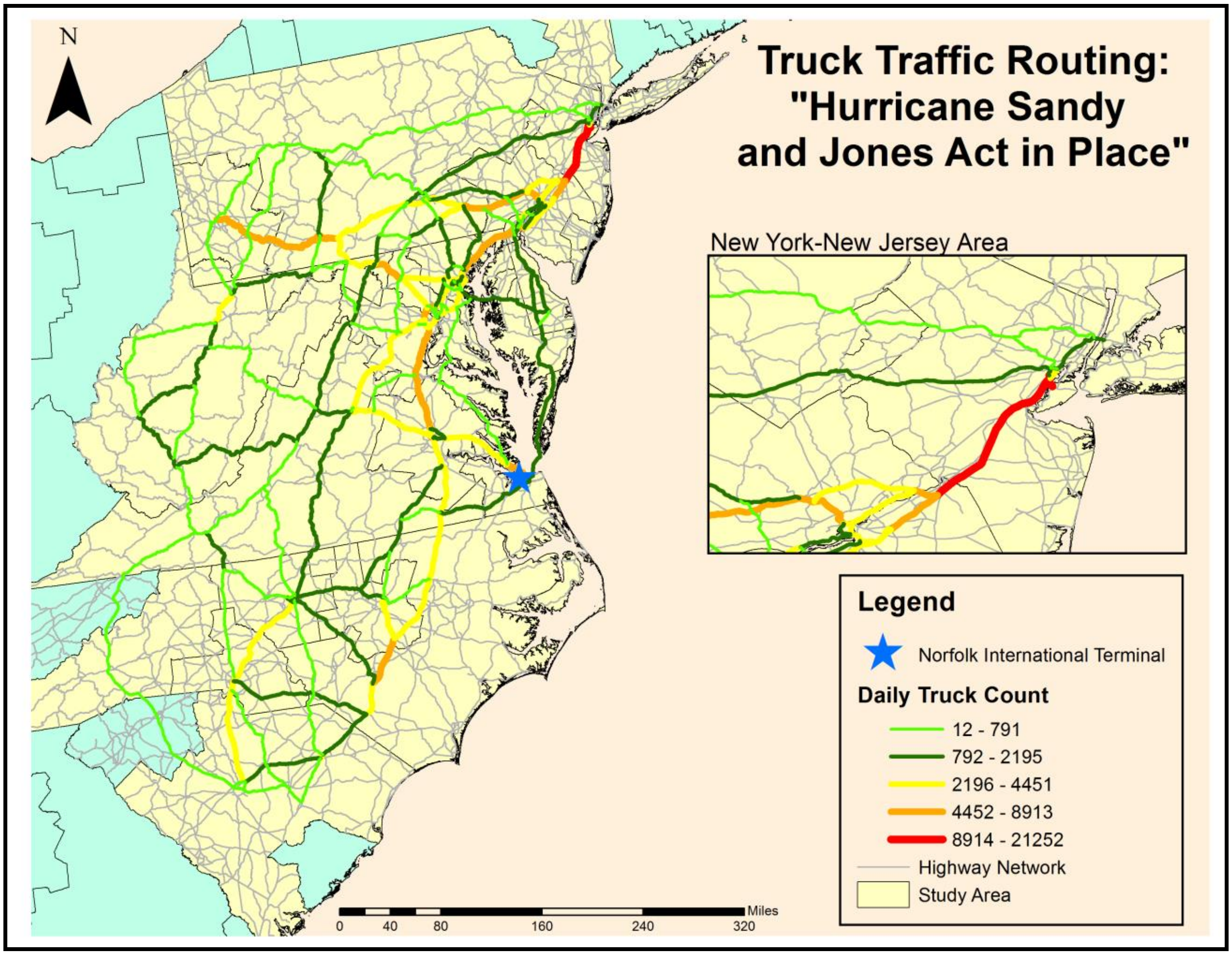

Figure 6.7: Daily Truck Counts resulting from Hurricane Sandy and Jones Act kept in place
Credit: M. Fialkoff (2017)

When comparing the truck counts and traffic patterns of Figure 6.5 and Figure 6.8, one area showing increased traffic was on the roadways in the immediate vicinity NIT. In Scenario 1, Terminal Road, the main access road for NIT, reported 4,900 trucks traversing the road; in comparison, Terminal Road in Scenario 2 had an increase in truck traffic to 7,800 trucks, approximately a 56% increase in truck traffic leaving NIT. When traffic from Terminal Road merges with Interstate 64, 5,000 trucks travel north to the Hampton Roads Bridge-Tunnel, a 44% increase in truck traffic in comparison to Scenario 1. For traffic heading south on Interstate 64 and then westward, 2,700 trucks traveled along this route, in comparison to 1,514 trucks, an 85% increase in trucks heading westward from NIT. When comparing U.S. Route 13, truck traffic increased from 500 trucks to 900 trucks, a 67% increase. Throughout the remainder of the highway network in the study area, truck volumes stay relatively constant, with no major changes in truck traffic on major highways such as I-95 or I-81.

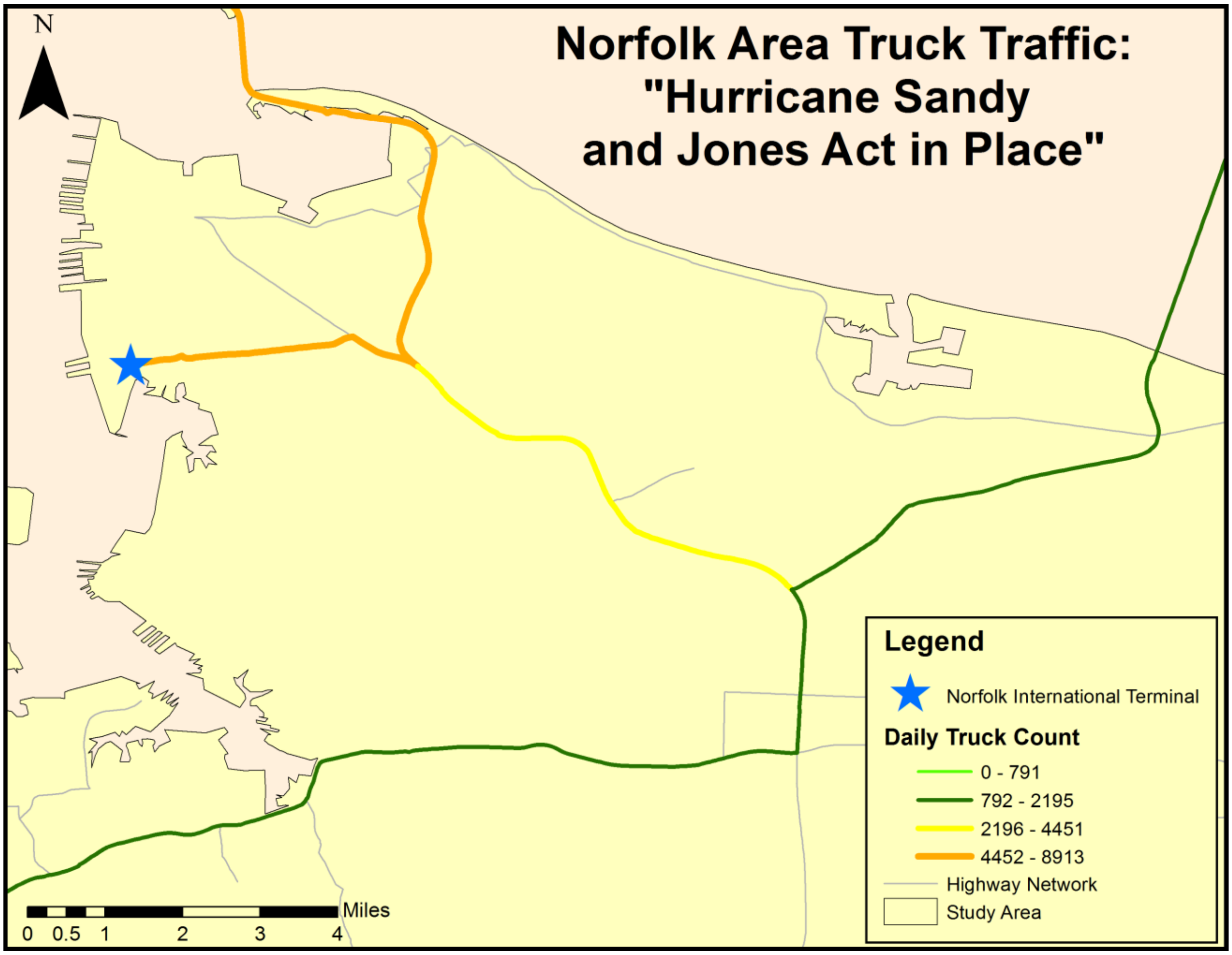

Figure 6.8: Norfolk Area Truck Traffic resulting from Hurricane Sandy
Credit: M. Fialkoff (2017)

6.3.2.2 Rail Traffic Analysis for Scenario 2

The remaining 1,584 containers that left NIT traveled by railroad. Based on the container data within the CCWS, one container is equivalent to one carload. As additional containers were added to a given waybill record, the carload value was increased by the number of additional containers. Using the modified carload values, Figure 6.9 illustrates the subsequent traffic volumes with additional cars added to the network. By adding containers using this method, the containers moved on existing trains, whereby the increase in container traffic would marginally increase the number of trains. From the perspective of the railroad companies, the primary concern with increased container traffic is the availability of vehicles to carry the container, less the ability to make trains that are long enough to justify the economic costs (Luebbers, 2016). Norfolk Southern reported having enough vehicles at NIT to handle increased container traffic and could add additional intermodal cars to existing trains leaving NIT to avoid adding additional trains to the network.

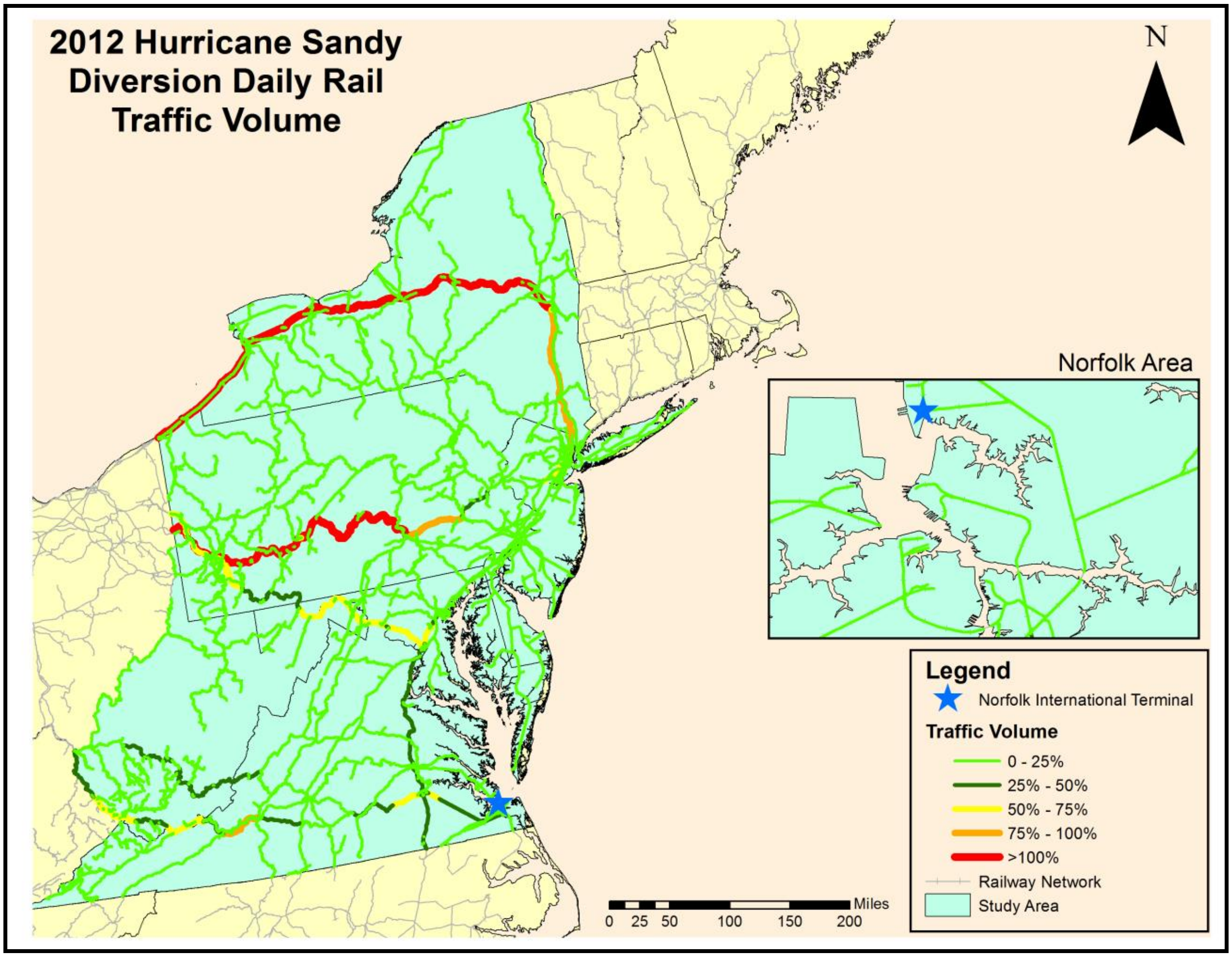

Figure 6.9: Daily Rail Traffic Resulting from Hurricane Sandy and Jones Act kept in place
Credit: M. Fialkoff (2017)

In comparing results between Scenario 1 and Scenario 2, there is no difference in traffic. This can be explained by the fact that the additional containers were added to additional trains and new trains were not created. Applying the same assumptions made by Dingler, Lai, and Barkan (2014) that intermodal container trains operating east of the Mississippi River carry approximately 110 cars, this value was used to build the trains used in this analysis. Even then, the additional containers were so small that such increases did not add trains to the network. Throughout the rail network within the study area, the values do not change between Scenario 1 and Scenario 2, even on the rail lines in the immediate vicinity of NIT. Given the traffic pattern for NIT as an "export facility," there was sufficient vehicles to handle the increased traffic flows (Luebbers, 2016).

6.3.3 Scenario 3: Hurricane Sandy Conditions-Jones Act Relaxed

In this scenario, the Jones Act restriction is relaxed. By relaxing the Jones Act, we allow diverted freight from Norfolk to travel via highway, railway, and waterway. Because no adequate demand schedule is in place to understand the willingness of customers to shift to short sea shipping, an assumption of modal parity is used for loading the network. By assuming modal parity between highway, railway, and waterway, the network is loaded with additional freight, assuming any of the three modal options are viable and the customer's options are of equal value.

6.3.3.1 Daily Truck Counts for Study Area

For this final scenario, of the 6,500 containers diverted to Norfolk because of Hurricane Sandy, only 2,167 containers left NIT via the highway. This compares to the 2,817 that left the facility when the Jones Act restriction stayed in place, resulting in a 23% decrease in truck traffic leaving from NIT based on the number of containers traveling by road haulage. Figure 6.10 highlights the daily truck counts resulting from an increase in container traffic, but in comparison to Scenario 2, the Jones Act restriction is relaxed and short sea shipping is available.

The results in this scenario are similar to the results reported in Scenario 2 and Figure 6.7 respectively because in Scenario 2, 2,100 containers left NIT by Columbia Coastal (Villa, 2016). In contrast to barges which can move at speeds between 8 – 10 knots, short sea shipping vessels can move at faster speeds, as high as 20 knots (Becker, Burgess, and Henstra, 2004), reducing the travel time reported by Villa (2016).

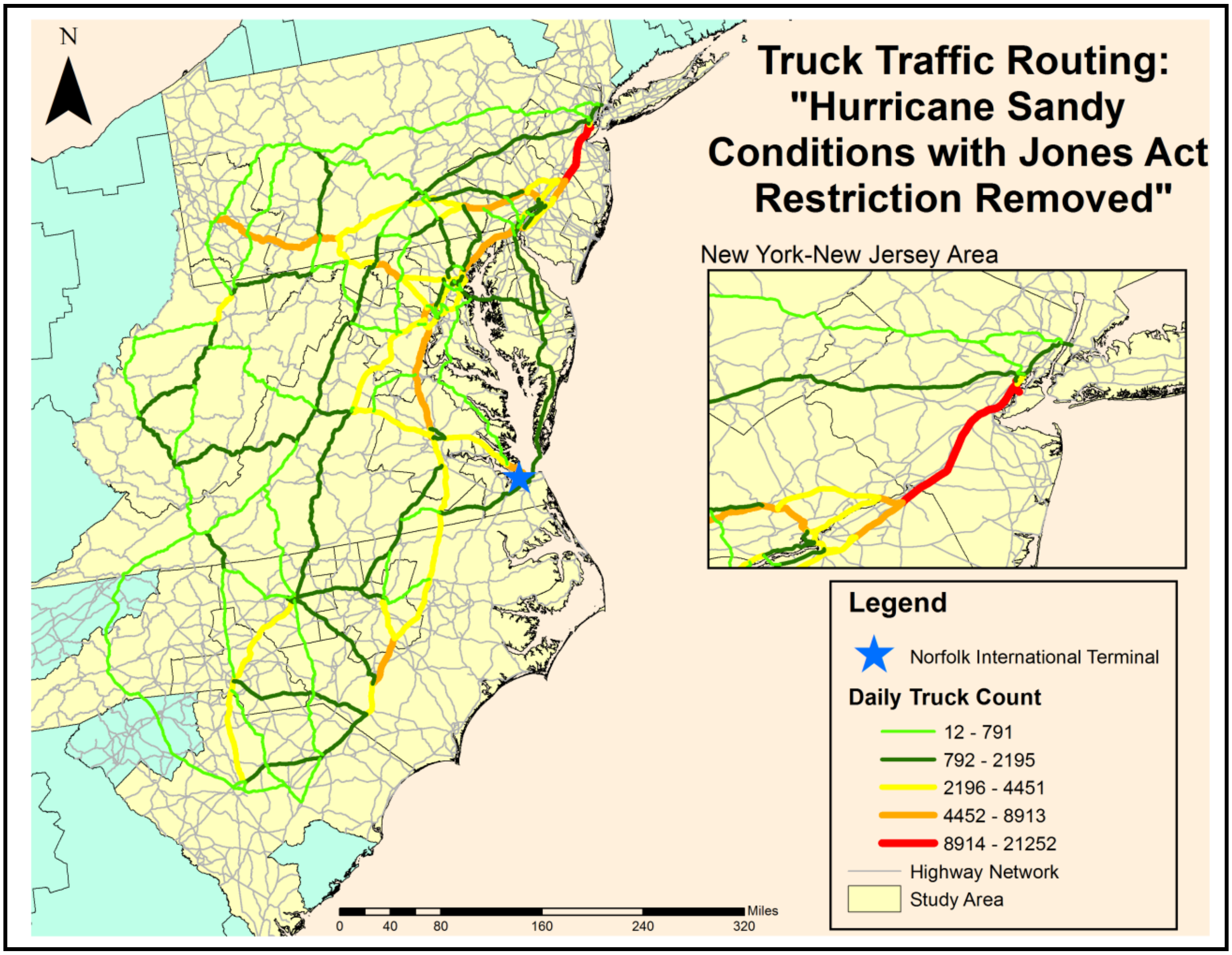

Figure 6.10: Daily Truck Counts resulting from Hurricane Sandy and Jones Act relaxed
Credit: M. Fialkoff (2017)

Similar to Scenario 1 and Scenario 2, the overall impact of increased truck traffic is minimal. As shown in Figure 6.11, the daily truck counts do not change across Scenarios 1 and 2. In the case of the local road network surrounding NIT, in comparison to 7,811 trucks traveling Terminal Road in Scenario 2, the introduction of a short sea shipping option drops that number down to 7,100, representing an 8% decrease in truck traffic along Terminal Road. A similar decrease is observed for truck traffic traveling towards the Hampton Road Bridge-Tunnel in Scenario 3. There is a 7% decrease from 5,000 trucks traveling across the bridge in Scenario 2, compared with 4,600 trucks traveling the same road segment in Scenario 3. For traffic traveling westbound on Interstate 64, there is an 11% decrease in truck traffic compared between Scenario 2 and Scenario 3. Like Scenario 2, throughout the remainder of the highway network in the study area, truck counts stay relatively constant, with no major changes in truck traffic on major highways such as I-95 or I-81.

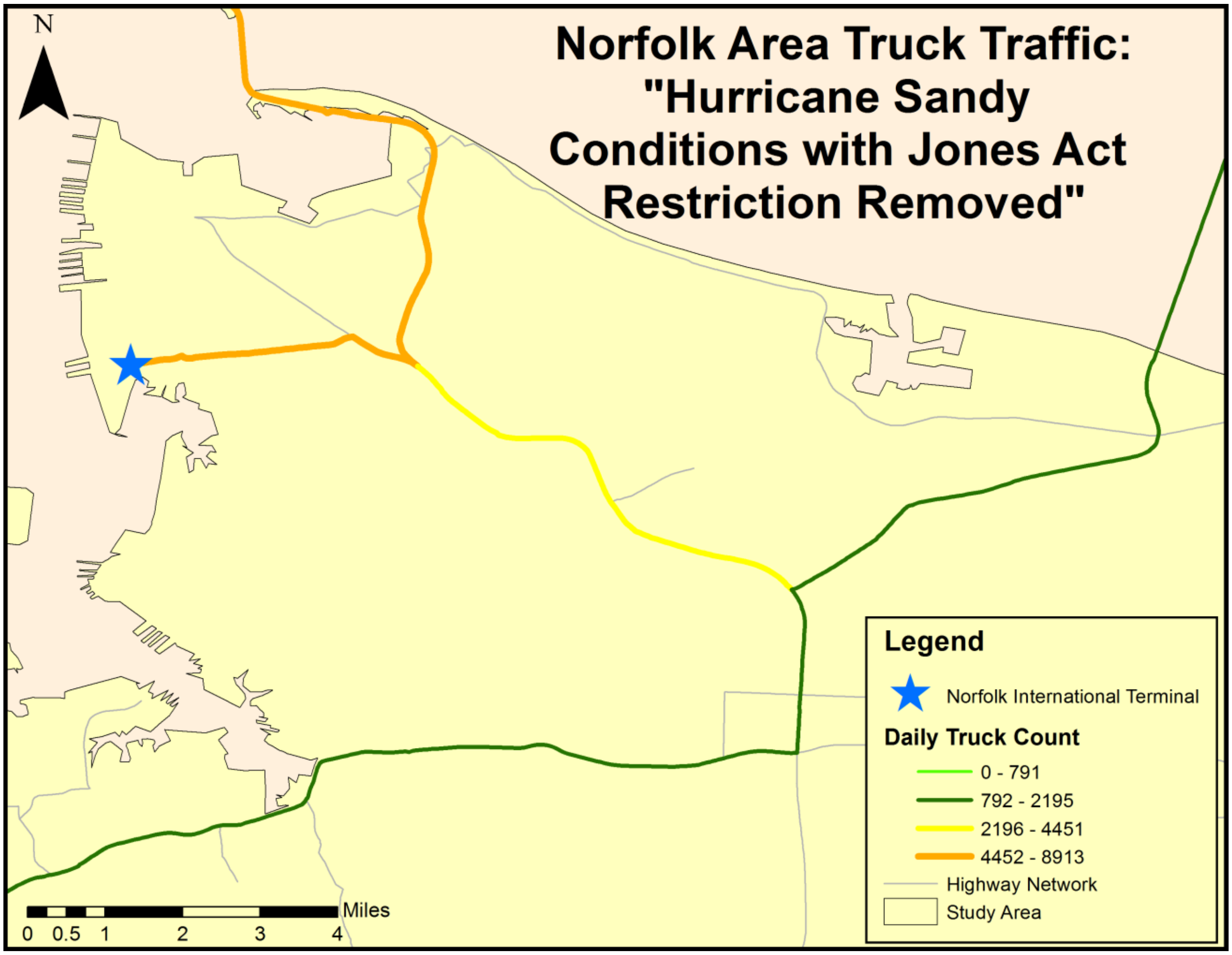

Figure 6.11: Norfolk Truck Traffic after Hurricane Sandy with the Jones Act Relaxed
Credit: M. Fialkoff (2017)

A similar decrease is seen along U.S. Route 13, where a 9% decrease is seen in trucks moving towards the Chesapeake Bay Bridge-Tunnel. In Scenario 2, 900 trucks were traveling along U.S. Route 13; in contrast, Scenario 3 saw 800 trucks traveling towards the Chesapeake Bay Bridge-Tunnel.

6.3.3.2 Rail Traffic Analysis for Scenario 3

In this scenario, compared to Scenario 2, there is an increase in containers leaving NIT via railroad. In the previous scenario, only 1,584 of the 6,500 containers diverted to NIT left via train; in this scenario, that number increased to 2,166, a 36% increase in possible rail traffic. As explained in Section 6.3.2.2, the method for incorporating the added containers into the existing rail traffic did not change, as illustrated in Figure 6.12.

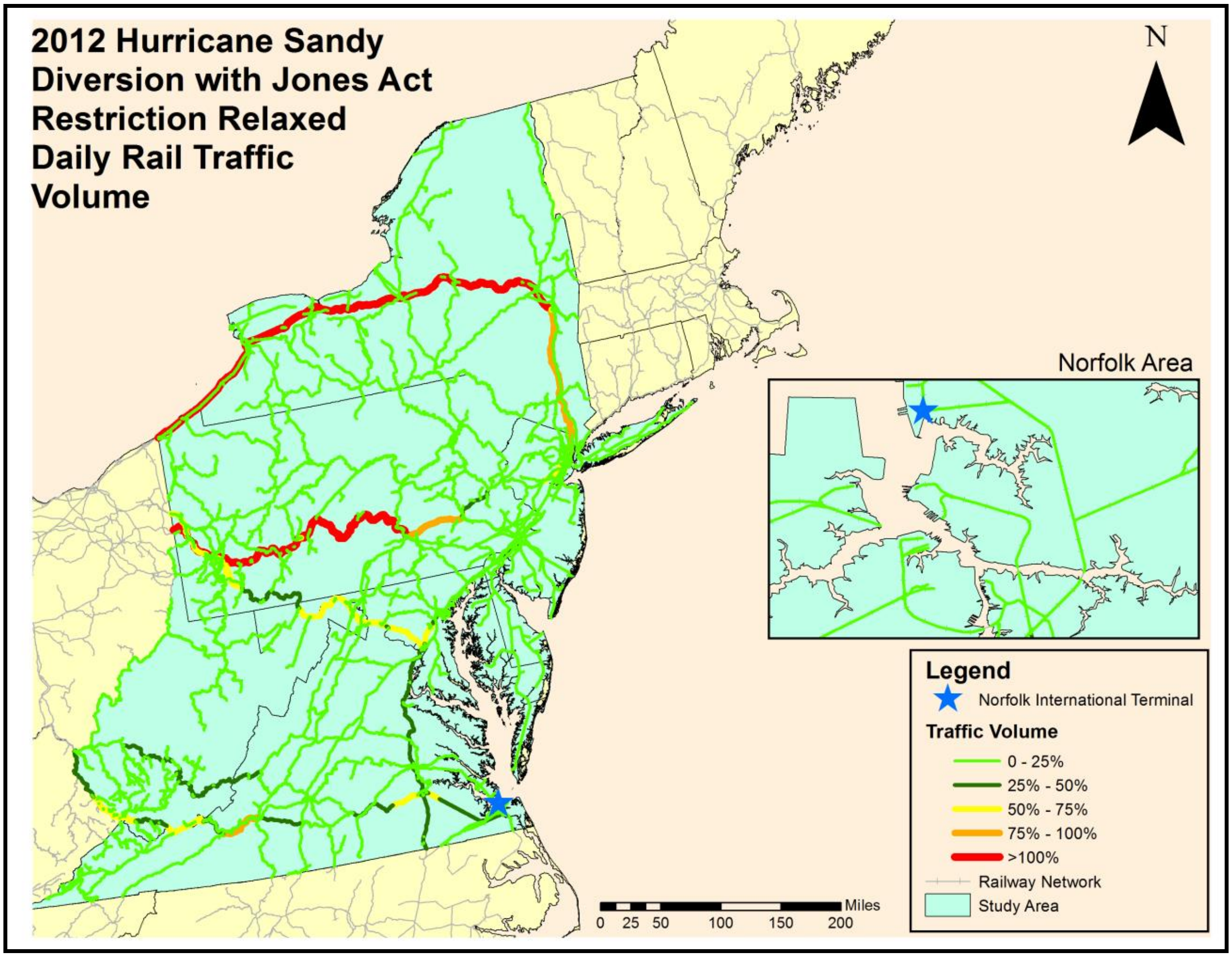

Figure 6.12: Daily Rail Traffic Resulting from Hurricane Sandy and Jones Act Relaxed
Credit: M. Fialkoff (2017)

Compared to the results reported in Scenario 1 and 2, the rail traffic in Scenario 3 did not any change with respect to increases in rail traffic, or potential bottlenecks, other than the CSXT Albany Division and the Norfolk Southern Harrisburg and Pittsburgh Divisions that were present in both Scenarios 1 and 2. These findings would suggest that the increase in container traffic generated because of Hurricane Sandy would not be affected by a change in the Jones Act; whether the restriction stayed in place or not is irrelevant for rail traffic, per the results reported within the 3 Scenarios.

6.3.3.3 Possible Short Sea Shipping Route

Unlike the highway and railway analyses described in the previous section, Figure 6.12 represents the possible short sea shipping route available from NIT to various terminals within the Port Authority of New York and New Jersey area affected by Hurricane Sandy. Under this scenario, the Jones Act restriction would be waived and available foreign vessels would be able to travel between ports.

The route generated by TRAGIS use the Atlantic Inter-coastal waterway system to travel to and from NIT and New York Harbor. The inset within Figure 6.13 illustrates the various routes for vessels either entering or exiting from New York harbor and the related Port Authority facilities. For the results shown here, the PANYNJ facilities chosen were facilities that supported container operations given the diversion of containers from New York to Norfolk. In the case of the Port of Newark and the Howland Hook Marine Terminal, the current project to “raise” the Bayonne Bridge would allow for container vessels to safely pass under the bridge, even using short sea shipping vessels in contrast to the Post-Panamax vessels for which the Bridge is being raised to accommodate.

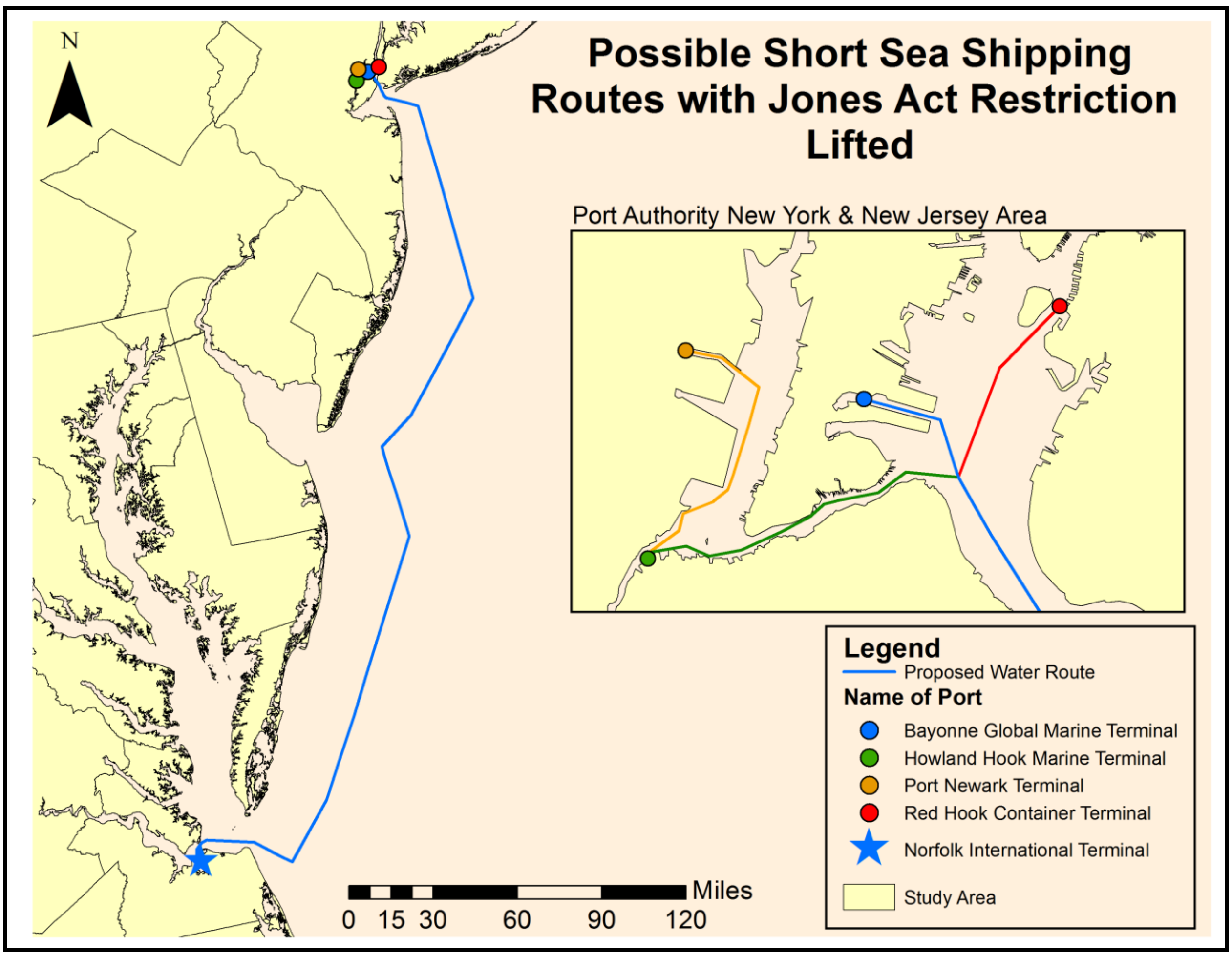

Figure 6.13: Possible Waterway Route if Jones Act was relaxed
Credit: M. Fialkoff (2017)

In comparison to the other mode analyses reported in this section, the waterway routes are generic insofar as the results only show the route, not the number of vessels needed to move diverted cargo, the capacity on the waterway, or the impact of the increased cargo loads moving through the port. The results in this discussion merely represent possible routes available for possible short sea shipping as a strategy the aftermath of a disruptive event. Chapter 8 will further elaborate on potential future research within the maritime transportation domain to further investigate the impact of short sea shipping in disaster contexts on ports.

6.4 Validation Analysis

Chapter 5 introduced the validation analysis for the highway and railway routes developed by the routing engine within TRAGIS. In Chapter 5, the Relative Root Mean Square Errors (RRMSE) measure was also introduced. The RRMSE is a statistical measure of the accuracy of the predicted route distances generated within TRAGIS compared to observed route distances from independent databases. The equation for the RRMSE is re-introduced in Equation 6-1:

$$RRMSE = \sqrt{\frac{\sum_{i=1}^{k}\left(\frac{P_i - O_i}{P_i}\right)^2}{k}} \qquad \textbf{(6-1)}$$

where

P_i	=	the predicted distance for route *i;*
O_i	=	the observed distance for route *i;*
RRMSE	=	Relative Root Mean Square Error;
k	=	the number of routes evaluated sampled.

For purposes of consistency of prior validation analysis, this dissertation uses the same process used by Pippen and Maheras (1995) when they conducted validation analysis for the routing algorithms for the legacy systems of TRAGIS, HIGHWAY, and INTERLINE. Because TRAGIS generated approximately 757 highway routes and 11,000 railway routes, a sample of routes was selected from the highway and railway batches. The acceptance criterion values used by Pippen and Maheras (1995) will also be used, as represented in Table 6.3.

Table 6.3: Acceptance Criterion Values for RRMSE Analysis

Condition	Criterion Range
Excellent	RRMSE ≤ 0.05
Acceptable	0.05 < RRMSE ≤ 0.10
Unacceptable	RRMSE > 0.10

Source: Pippen and Maheras (1995)

Using a similar approach taken by Pippen and Maheras (1995), the sample routes chosen for both the highway and railway validation analysis used the Norfolk International Terminal (NIT) as the origin. The following sections report the findings from the highway and railway validation analyses, respectively.

6.4.1 Highway Validation Analysis

For the highway validation analysis, 22 of the 757 routes generated originated from the Norfolk International Terminal. The results from the validation analysis for the highway analysis are presented in Table 6.4. Using Google maps as the independent database for highway routing, the validation analysis resulted in 22 routes returning RRMSE values under 0.05. Per the acceptance criterion reported in Table 6.3, RRMSE values under 0.05 indicates that the predicted routes are accurately reporting route distance in comparison to the independent database. In most instances, the predicted routes were shorter than the observed route, with most routes being between five to fifteen miles shorter than the observed route. Except for one route, the percent difference between the predicted and observed routes ranged from 0.6% to 7.4%. When analyzing the RRMSE for all 22 routes, the RRMSE value is 0.0479, which again satisfies the acceptance criterion. When comparing the analysis conducted in this dissertation with the validation analysis conducted for the HIGHWAY routing algorithm, the results are consistent with those of Pippen and Maheras (1995). This indicates that the routing algorithm is accurately predicting a similar route to that of the independent database.

Table 6.4: Highway Validation Analysis with NIT Centralization

NIT to	1	2	3	4	[(P-O)/P]	[(P-O)/P]^2	Condition
Baltimore	211.6	237	-25.4	10.7	-0.12004	0.01441	Excellent
Charlotte	327.2	336	-8.8	2.6	-0.02689	0.00072	Excellent
DC Part-Washington	186.9	192	-5.1	2.7	-0.02729	0.00074	Excellent
DE Part-Philadelphia	236.4	248	-11.6	4.7	-0.04907	0.00241	Excellent
Greensboro	247.7	245	2.7	1.1	0.01090	0.00012	Excellent
Maryland Part-Washington	201.4	206	-4.6	2.2	-0.02284	0.00052	Excellent
NJ Part-NYNJPACT	338.1	356	-17.9	5.0	-0.05294	0.00280	Excellent
NJ Part-Philadelphia	261.9	278	-16.1	5.8	-0.06147	0.00378	Excellent
NY Part-NYNJPACT	333.5	349	-15.5	4.4	-0.04648	0.00216	Excellent
PA Part-Philadelphia	263.9	278	-14.1	5.1	-0.05343	0.00285	Excellent
Pittsburgh	412.5	419	-6.5	1.6	-0.01576	0.00025	Excellent
Raleigh Durham	187.1	202	-14.9	7.4	-0.07964	0.00634	Excellent
Remainder of Delaware	160.2	162	-1.8	1.1	-0.01124	0.00013	Excellent
Remainder of Maryland	253.9	262	-8.1	3.1	-0.03190	0.00102	Excellent
Remainder of New Jersey	278.5	294	-15.5	5.3	-0.05566	0.00310	Excellent
Remainder of North Carolina	239.3	232	7.3	3.1	0.03051	0.00093	Excellent
Remainder of Pennsylvania	287.9	295	-7.1	2.4	-0.02466	0.00061	Excellent
Remainder of South Carolina	378.2	394	-15.8	4.0	-0.04178	0.00175	Excellent
Remainder of Virginia	149.7	160	-10.3	6.4	-0.06880	0.00473	Excellent
Richmond	89.5	90	-0.5	0.6	-0.00559	0.00003	Excellent
Virginia Part-Washington	185.6	184	1.6	0.9	0.00862	0.00007	Excellent
West Virginia	392.1	405	-12.9	3.2	-0.03290	0.00108	Excellent
Maximum			7.30	10.72			
Minimum			-25.40	0.56			
Mean			-9.13	3.79			
Standard Deviation			7.86	2.44			
Relative Root Mean Square Error (RRMSE)	**0.04794**	**Excellent**					
N = 22							

Credit: M. Fialkoff (2017)

Header Number	Description
1	**TRAGIS Distance (miles) (P)**
2	**Total Distance (miles) (O)**
3	**Difference between TRAGIS and Total**
4	**Absolute Value of Percent Difference**

6.4.2 Railway Validation Analysis

For the railway validation analysis, the development of the sample required holding constant the originating rail company, in addition to the selection of NIT as the origin. In Chapter 5, the rail routing algorithm required an originating and terminating rail company for route generation. Whereas the highway routes are agnostic to which truck carrier is moving over the highway, the connection between rail carrier and the rail infrastructure over which they operate is critical. When reviewing the routes where NIT was the origin, all the origin railroad companies were for Norfolk Southern. Albeit a few routes that transferred to short-lines; a sample of twenty-two routes were selected where NIT was the origin, with NS being the originating and terminating railroad.

Originally, the independent database that the TRAGIS route distances were compared to were the total distance value within the CCWS. As discussed previously, the tool used by the CCWS to determine this value was the Princeton Transportation Network Model (PTNM). Because limited documentation was available to understand the PTNM, Norfolk Southern supplied independent distance values (LoSapio, 2016). Although the CCWS internal distance values were not used, Table 6.5 reflects the validation analysis using the Norfolk Southern values, but shows the values from the CCWS and compares the difference between the three distances.

Similar to the highway route validation analysis, each of the twenty-two individual rail routes returned RRMSE values under 0.05, indicating an excellent result under the acceptance criterion. Again, this indicates that at the individual route level, the predicted distance values reported by TRAGIS are accurate in comparison to the distances reported by Norfolk Southern. When examining the percent difference between the two data points, the percent difference ranged from 0.5% to 7.7%, indicating the predicted routes were pretty accurate in their distances in comparison to the Norfolk Southern provided values.

Table 6.5: Railway Validation Analysis with NIT Centralization

NIT to	1	2	3	4	5	6	7	[(P-O)/P]	$[(P\text{-}O)/P]^2$	Condition
Atlanta	658.1	673.3	673.7	15.60	15.20	0.40	2.3	-0.023097	0.000533	Excellent
Chicago	1046.4	1028.3	1070.9	24.50	18.10	42.60	1.8	0.017297	0.000299	Excellent
Decatur	1116.9	1115.1	1115.0	1.90	1.80	0.10	0.2	0.001612	0.000003	Excellent
Sauget	1225.8	1095.2	1098.0	127.80	130.60	2.80	11.9	0.106543	0.011351	Excellent
Louisville	825.3	822.6	819.0	6.30	2.70	3.60	0.3	0.003272	0.000011	Excellent
Detroit	870.8	866.2	1019.5	148.70	4.60	153.30	0.5	0.005282	0.000028	Excellent
Kansas City	1452.9	1366.3	1366.8	86.10	86.60	0.50	6.3	0.059605	0.003553	Excellent
St-Louis	1226.6	1101.3	1097.5	129.10	125.30	3.80	11.4	0.102152	0.010435	Excellent
Greensboro	307.8	321.8	321.1	13.30	14.00	0.70	4.4	-0.045484	0.002069	Excellent
Cleveland	839.3	828.1	828.0	11.30	11.20	0.10	1.4	0.013344	0.000178	Excellent
Maple Heights	842.4	838.4	916.1	73.70	4.00	77.70	0.5	0.004748	0.000023	Excellent
Columbus	677.2	669.4	672.0	5.20	7.80	2.60	1.2	0.011518	0.000133	Excellent
Sharonville	784.9	774.2	858.9	74.00	10.70	84.70	1.4	0.013632	0.000186	Excellent
Cincinnati	799.9	789.9	844.2	44.30	10.00	54.30	1.3	0.012502	0.000156	Excellent
Memphis	940.1	968.8	963.3	23.20	28.70	5.50	3.0	-0.030529	0.000932	Excellent
Front Royal	380.1	406.3	405.9	25.80	26.20	0.40	6.4	-0.068929	0.004751	Excellent
Garden City	933.3	734.4	945.3	12.00	198.90	210.90	27.1	0.213115	0.045418	Excellent
Georgetown	781.4	779.4	777.1	4.30	2.00	2.30	0.3	0.002560	0.000007	Excellent
Shreveport	1368.8	1270.5	1310.2	58.60	98.30	39.70	7.7	0.071815	0.005157	Excellent
Elizabeth Port	690.7	706.5	713.9	23.20	15.80	7.40	2.2	-0.022875	0.000523	Excellent
Discovery Park	662.9	662.0	661.7	1.20	0.90	0.30	0.1	0.001358	0.000002	Excellent
Charleston	640.9	648.0	704.9	64.00	7.10	56.90	1.1	-0.011078	0.000123	Excellent
Maximum				148.70	198.90	210.90				
Minimum				1.20	0.90	0.10				
Mean				44.28	37.30	34.12				
Standard Deviation				45.21	54.29	55.76				
Relative Root Mean Square Error (RRMSE)	**0.062476**	**Acceptable**								
N = 22										

Credit: M. Fialkoff (2017)

Header Number	Description
1	**TRAGIS Distance (miles) (P)**
2	**NS Total Distance (miles) (O)**
3	**CCWS Total Distance (miles)**
4	**Δ between TRAGIS and CCWS**
5	**Δ between TRAGIS and NS**
6	**Δ between NS and CCWS**
7	**% Δ between TRAGIS and NS**

In some instances, particularly for the routes between NIT and Louisville, St. Louis, and Garden City, the predicted distance value reported by TRAGIS was off from the value reported by Norfolk Southern in some instances by 190 miles, that is, approximately 10%-11%, with the highest difference between two values at 27%. In trying to explain these deviations, possible explanations include trackage or haulage rights that are not reflected within the railway network or segments of the railway network have been deactivated even though they may still be operating today. Particularly in West Virginia, while portions of the network have been deactivated at the time these routes were run because they were primarily used for coal traffic, they may have been used as mixed traffic corridors, not reflected in the railway network attribute table.

In contrast to the highway validation analysis and the Pippen and Maheras (1995) report on the INTERLINE code, the overall RRMSE value for the selected railway routes was 0.062 which fell within the acceptable category. This result indicates that while the routes individually are accurately predicting the observed routes from the independent databases, there is room for improvement. For those routes where large differences were observed, the results may have pushed the RRMSE over the 0.05 threshold separating the excellent and acceptable designations.

6.5 Discussion

6.5.1 Effect of the Jones Act on Freight Transportation Networks

Chapter 4 presented the following research question regarding the relationship between the Jones Act and freight movements in the aftermath of a disruptive event, such as Hurricane Sandy:

1. *What effect does the imposition and subsequent relaxation of the Jones Act have on freight transportation networks experiencing disruption?*

From this primary research question, two sub-questions focused on individual mode impact if the Jones Act restriction on short sea shipping stayed in place in the aftermath of a disruptive event, such as Hurricane Sandy:

a. *What effect does the imposition and relaxation of the Jones Act have on the movement of goods over highway networks experiencing disruption?*
b. *What effect does the imposition and relaxation of the Jones Act have on the movement of goods over railway networks experiencing disruption?*

Prior to analyzing the scenarios developed in this chapter, the following hypotheses were also presented as to the effect of the Jones Act on highway and railroad freight movements in the aftermath of a disruptive event:

- *Hypothesis 1a: Relaxing the Jones Act under disruptive circumstances will not significantly increase truck link flow traffic over the highway.*
- *Hypothesis 1b: Relaxing the Jones Act under disruptive circumstances will not change traffic patterns on railways experiencing increased traffic demand.*

From the scenarios, the highway network did not see a major change in truck traffic across links through the network. When comparing the results between Scenario 1, 2, and 3, the only area where truck traffic significantly increased was in the immediate area surrounding NIT. Table 6.6 reflects the change in truck traffic for three road segments in the immediate vicinity of NIT, Terminal Road, Interstate 64 heading north towards the Hampton Roads Bridge-Tunnel, and Interstate 64 heading south towards points west of NIT.

Table 6.6: Daily Truck Traffic on Selected Links near NIT

	Scenario 1	**Scenario 2**	**Scenario 3**
Terminal Road	4,900	7,800	7,100
Interstate 64 North (Hampton Roads Bridge Tunnel)	3,400	5,000	4,600
Interstate 64 South (Points west)	1,500	2,700	2,400
U.S. Route 13 approaching Chesapeake Bay Bridge-Tunnel	500	900	800

Credit: M. Fialkoff (2017)

Between Scenario 1 and Scenario 2, there was a 56% increase in truck traffic because of increased trucks leaving NIT, however, when the truck traffic of Scenario 2 is compared with that of Scenario 3, there is an only an 8% decrease in truck traffic if the Jones Act restriction was removed. Compared between Scenario 1 and Scenario 3, there is a 43% increase in traffic if the Jones Act was removed, compared to 56% if the Jones Act remained in place. Elsewhere throughout the network, there was increased truck traffic seen, but not enough to cause bottle necks across the network, including major Interstates such as I-81 and I-95.

For rail traffic increases, the results from Scenario 2 and Scenario 3 indicate that the increased containers leaving NIT via rail did not cause capacity bottlenecks or disrupt the rail network any further than regular baseline traffic as reported in Scenario 1. These results are consistent with reporting by Luebbers (2016) that given the fact that the storm hit New York, whose port was an import facility, and missed NIT, which is considered an export facility, there were sufficient vehicles for handling increased containers moving through NIT.

While these results show that the Jones Act restriction and its subsequent relaxation would not have a significant impact on highway or railway haulage of freight, there are some aspects that require consideration with respect to these results. First, the assignment methodology used consisted of a shortest path solution rather than the more representative Stochastic User Equilibrium as reported by Battelle (2011). While the shortest path solution is a viable assignment methodology, it can lead to portions of the network receiving higher traffic than would in reality. In this analysis, Scenario 1 illustrated this issue with lower truck counts along the I-81 corridor than were previously reported by VDOT (n.d.). Although this would seem to be problematic, given the context of understanding diversion of freight, the implementation of the shortest path algorithm is appropriate (Georgia Tech Research Corporation *et al.* 2012; Schulz, 2011).

A second consideration is the scale of the analysis. The scenarios generated looked at the macro level impacts of the Jones Act restriction and how highway and railway traffic would be affected if the Jones Act restriction was relaxed. While Table 6.6 highlights local impacts of increased truck traffic on the immediate highway network surrounding NIT, there was limited large-scale network effects from the results presented. In both the highway and railway cases, the main datasets used were the FAF and the CCWS. For this research, data for passenger traffic and regional rail traffic was not available. In some ways, this was problematic, but also could be argued to be *de minimis* given the circumstances the study was examining. In the case of railways, the study area included the Northeast Corridor, a generally congested rail corridor given various passenger rail services and freight operators sharing track (Krier *et al.* 2014). In the results presented, the Northeast Corridor shows low rail traffic, indicating the absence of regional services such as Metro-North, Amtrak, SEPTA, and other commuter lines that utilize the same segments of track. In the aftermath of Hurricane Sandy, passenger service in the Northeast was severely damaged due to flooding of local tracks and disruption of electrical systems for switching track (Flynn, 2015). This would suggest that where passenger service may be diminished, freight operations outside the affected area can continue unimpeded.

The results indicate that the waiver of the Jones Act would not impact highway or railway traffic in the aftermath of a disruption. While Southworth *et al.* (2014) argued that having a water-borne modal option would lend itself to the concept of *modal flexing*, or a more robust freight network as described by Ta, Goodchild, and Pitera (2009), the real question becomes, at what cost? If the Jones Act restriction is not causing severe congestion or traffic constraints on the highway or railway networks then to relax the restriction would be to what end? As will be discussed in Chapter 7, the history and policy implications of the Jones Act would militate towards keeping the restriction in place, with waivers granted only under certain conditions.

6.5.2 Using Transportation Data for Freight Policy Analysis

The second research question presented in Chapter 4 related to the implementation of transportation data for policy research and asked the following:

> *How can existing transportation data be implemented to study policy-based interventions on transportation networks?*

The processes described in Chapters 4 and 5 for converting the Freight Analysis Framework (FAF) and the Confidential Carload Waybill Sample (CCWS) from economic and transportation flow data to routable, geo-spatially enabled data provided the foundation for undertaking the analysis. Whereas the FAF has already been calibrated to an existing network (Battelle, 2011), research focused on conversion and calibration of the CCWS to a transportation network has been limited. Krier *et al.'s* (2014) study of freight capacity delays resulting from Amtrak and commuter lines in the Northeast Corridor highlighted how the waybill sample can be flowed over a railway network. In that case, the authors also used the ORNL Railway Network, but did not explain the process for converting the waybill data into routable, geo-spatially enabled data. Similarly, freight capacity research by Cambridge Systematics (2007) did not explain their methodology for converting economic data into geo-spatially explicit routes.

Through the process described in Chapter 5, this research highlights how economic data such as the CCWS can be converted into geo-spatially enabled routes for a transportation network. In this case, the waybills were linked to the ORNL railroad network; however, the process described is transferable to other railway networks. This type of procedure can be useful for visualizing railway traffic patterns and provide further useful tools in transportation policy research as it relates to railways, traffic, and understanding flow in a visual medium.

6.6 Summary

While the Jones Act increases traffic on freight transportation networks experiencing a disruptive event, the relaxation of the restriction on short sea shipping would not affect the traffic flow macroscopically, for either trucks or trains within the network. Although previous research has speculated as to the impact of relaxing the Jones Act, these results indicate that relaxation of the Jones Act would not have a significant impact on transportation networks handling increased freight traffic at the regional level. The results indicate that on local roads surrounding NIT, there would be significant increases in truck traffic. While the results reported in the scenarios indicate that the Jones Act restriction has a negligible impact on the highway and railway network, the previous discussion highlights some issues encountered, particularly with the assignment methodology and the availability of passenger data to add further resolution to the results provided.

With that said, the results at large answer two of the three questions asked in Chapter 4. First, the results in this chapter indicate how a law such as the Jones Act can affect transportation networks experiencing disruption. Second, the process described in Chapter 5 for converting economic data related to railway freight into geo-spatially enabled routes provided a platform to study the practical implications of a law like the Jones Act and how those results are visualized for further analysis.

While the previous chapters focused on the practical implications of the Jones Act on freight disruption, the next chapter will focus on the legal challenges associated with the Jones Act Waiver process; addressing the concerns raised by Flynn (2015) as to the ad hoc nature of obtaining a Jones Act waiver.

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Chapter 7: Legal Analysis of the Jones Act Waiver Process

7.1 Introduction

The previous chapters examined the effect of the Jones Act on freight transportation networks and how the restriction on short sea shipping affected movement in the aftermath of Hurricane Sandy. Using the Scenarios described in Chapter 6, the effect of removing the Jones Act restriction on short sea shipping is negligible. While Scenario 3 illustrated what a "Jones Act free" environment would look like in the aftermath of a disruption, the impact of keeping the Jones Act in place does not meaningfully impact the effect of increased freight traffic.

In contrast to the previous chapters that used the Jones Act to test the impact of the Statute on freight transportation networks, this chapter focuses on the regulatory process involved with the granting of waivers under the Jones Act. Returning to the System of Systems framework, Figure 7.1 shows the focus of this chapter is on the law and its administration, rather than its effect on the physical transportation network.

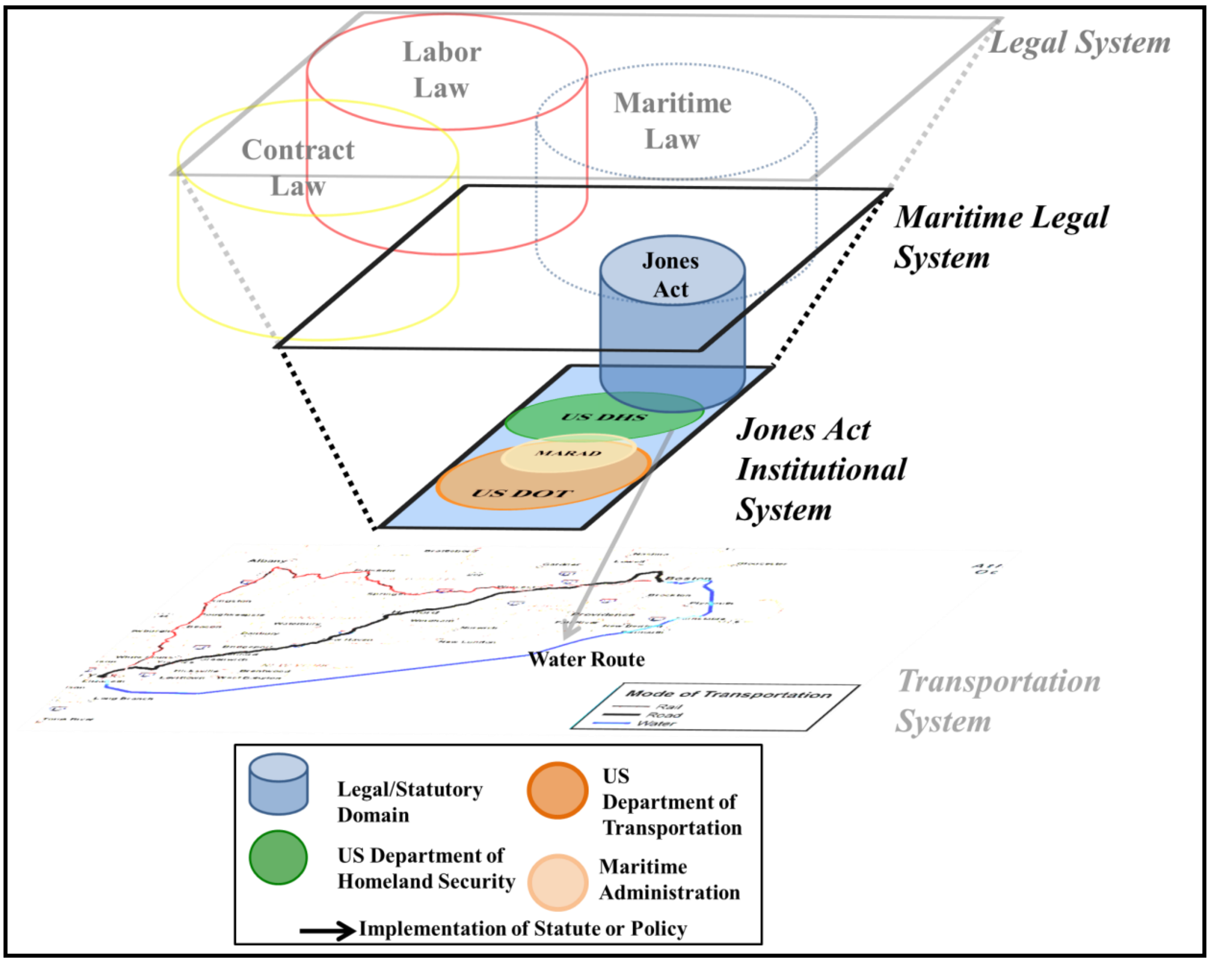

Figure 7.1: System of Systems Framework Focusing on the Jones Act and its Implementation
Credit: M. Fialkoff (2017)

In his report on the impact of Hurricane Sandy on the transportation sector, Flynn (2015) critiqued the Jones Act waiver process as being “ad hoc” in nature in determining which vessels were eligible for waiver, with limited predictability; with such a process posing a barrier to freight network recovery. The “ad hoc” process described by Flynn is a result of the statutory language and the regulatory processes in place with respect to Jones Act waivers; specifically, the opaqueness of the guidance for obtaining a Jones Act waiver and under what guidelines or standards are such decisions made. Most recently, the Federal District Court for Alaska held that Jones Act waiver decisions were unreviewable by the courts as such decisions are “committed to agency action” (*Furie Operating Alaska v. United States Department of Homeland Security*, 2015).

The decision in *Furie* reinforces the critique that the guidelines and standards for obtaining a Jones Act waiver are obscure. Although *Furie* did not pertain to a disaster-context, the holding illustrates the obscurity of the definition of “in the interest of natural defense” as it relates to Jones Act waiver decisions. The Department of Defense (DOD), the Department of Homeland Security (DHS), and the Maritime Administration (MARAD) not providing clear guidelines or standards for rendering Jones Act waiver decisions exacerbate this ambiguity. As highlighted in recent natural disasters such as Hurricane Sandy in 2012 and the Polar Vortex in 2014, inconsistencies exist for granting Jones Act waiver applications. From the perspective of resilience planning and the ability for the law to be adaptive, this lack of guidance illustrates how a law can act as a barrier to resilience.

This chapter provides a brief history behind U.S. cabotage laws and introduces the Jones Act. From there, the chapter focuses on the operative language for obtaining a Jones Act waiver. This portion of the chapter identifies the agencies involved with enforcing the provisions of the Jones Act and list recent natural disasters where individuals filed for Jones Act waivers. In two cases, Hurricane Sandy and the Polar Vortex, DHS denied Jones Act waivers, citing grounds that the applications did not meet the “national defense” exception ascribed in the statute. The chapter then turns to the recent *Furie* opinion, highlighting the district courts deference to the agency’s decision in Jones Act waiver cases. Finally, the chapter concludes by proposing administrative reforms and/or policy prescriptions for clarifying the Jones Act waiver process, including Congressional intervention, regulatory reform, and leaving the law as is.

7.2 A Brief History of U.S. Cabotage Law

The right of a Sovereign to regulate laws of trade and commerce within one's domestic waters, also known as *cabotage*, predates the founding of the United States. Today, cabotage laws exist in many countries including the United States, Australia, and the European Union. The derivation of the word cabotage comes from the French word, *caboter*, which translated means "to sail along the coast" (Smith, 2004).

Upon its founding, the United States began to develop its own cabotage laws. The first Congress took a variety of legislative actions to protect domestic shipping interests, namely by enacting tariffs and rules on which vessels could be registered for domestic trade (Leback and McConnell, 1983). The Act of 1789 placed a tariff on all goods imported, with a 10% reduction in the tariff if the goods arrived on an American vessel. In 1790, Congress passed another statute, placing further tonnage duties on imported goods.

Throughout the 18th and 19th centuries, domestic shipping saw periods of expansion and contraction. While the Civil War period saw a decline in shipping, expansion of the country in the late 19th and early 20th century to include territories of Hawaii and Puerto Rico and the construction of the Panama Canal provided ample trade opportunities (Whitehurst, 1985). The problem that domestic shipping encountered was one of economics. The high cost of shipping on American vessels within domestic waters forced shippers to push costs onto customers. Over time, the decision to ship goods by water became too expensive, with rail and road transportation providing cheaper alternatives (Whitehurst, 1985).

The events of World War I led to a crisis for U.S. shipping and the availability of vessels for national defense and security and the eventual genesis for the Jones Act. In the years prior to the United States entering World War I, Congress passed the Shipping Act of 1916 (Yost 2013). The Act called for the creation of the Shipping Board to construct U.S. vessels for steamship services (Yost, 2013). Although the Shipping Board provided funding for constructing U.S. vessels, by the time the U.S. declared war on Germany in 1917, the Shipping Board realized it did not have enough vessels to support U.S. war efforts. In response, the Shipping Board created a subsidiary organization, the Emergency Fleet Corporation, with the sole purpose of constructing vessels to support the U.S. military (Yost, 2013). On the home front, the Shipping Board suspended the restriction on foreign-built vessels from engaging in domestic trade for the duration of the war and for 120 days after the War's conclusion (Leback and McConnell, 1983).

As part of their efforts, the Shipping Board and the Emergency Fleet Corporation constructed 1,409 vessels for service, though their need never fully utilized as World War I ended in 1918 (Smith, 2004).

Given the government surplus of vessels and the need for the Shipping Board to get out of the shipbuilding industry, Congress passed the Merchant Marine Act of 1920. Sponsored by Senator Wesley Jones from the state of Washington, the primary purpose of the legislation "[was] an earnest effort to lay the foundation of a policy that will build up and maintain an adequate American merchant marine in competition with shipping of the world (Jones, p.233, 1921)." The original purpose for the Jones Act had less to do with cabotage and more to do with the development of an economic stabilization for selling off vessels built by the government during World War I (Yost, 2013). The Statute enabled the Shipping Board to sell the excess vessels to private operators at a deep discount (Yost, 2013).

7.3 The Merchant Marine Act of 1920 – "The Jones Act"

Sponsored by Senator Jones, the original draft of the Merchant Marine Act of 1920 was a fifty-nine-page bill with 149 amendments and a thirty-six-page conference report (Whitehurst, 1985). Within the conference report, no mention was made of the cabotage provisions (Whitehurst, 1985). According to Whitehurst, "[t]he sense of Congress was clear: a protected U.S. domestic-trade merchant fleet would be the cornerstone of any future American maritime policy (Whitehurst, p. 13, 1985)."

7.3.1 Operative Sections of the Merchant Marine Act of 1920

The Merchant Marine Act and its provisions are located under Title 46, Subtitle V of the United States Code. Section 55102 (b) of Title 46 pertaining to the restriction on vessels engaged in coastwise trade reads in relevant part:

> Except as otherwise provided in this chapter or chapter 121 of this title, a vessel may not provide any part of the transportation of merchandise by water, or by land and water, between points in the United States to which the coastwise laws apply, either directly or via a foreign port, unless the vessel (1) is wholly owned by citizens of the United States for purposes of engaging in the coastwise trade; and (2) has been issued a certificate of documentation with a coastwise endorsement under chapter 121 or is exempt from documentation but would otherwise be eligible for such a certificate and endorsement (46 U.S.C. § 55102 (b), 2017).

Under this provision of the Statute, vessels not constructed in the U.S. or owned by American citizens (or corporations) can engage in coastwise trade within the United States. This means that a vessel built outside the United States and not owned by an American or an American corporation cannot transport goods between two ports within the U.S. Vessels found in violation of § 55102 (b) are subject to the provisions of § 55102 (c), which reads:

> Merchandise transported in violation of subsection (b) is liable to seizure by and forfeiture to the Government. Alternatively, an amount equal to the value of the merchandise (as determined by the Secretary of Homeland Security) or the actual cost of the transportation, whichever is greater, may be recovered from any person transporting the merchandise or causing the merchandise to be transported (46 U.S.C. § 55102 (c), 2017).

The penalty for moving cargo between two U.S. ports on a non-Jones Act vessel could either surrender their cargo to the U.S. Government or pay a fine that equals the value of the cargo on the vessel. Under the Jones Act, the Department of Homeland Security (DHS) is responsible for enforcing the Jones Act; specifically, the vessel, crewing, and ownership requirements. Customs and Border Protection (CBP) is the agency within the DHS that review documentation and crew manifests to ensure Jones Act compliance.

7.4 The Jones Act Waiver Provision

Within the provisions of the Statute, § 501 of Title 46 of the United States Code provides a waiver process for setting aside the provisions of § 55102 to allow non-Jones Act vessels to engage in coastwise trade. Section 501 provides two pathways for obtaining the waiver, as illustrated in Figure 7.2. The first path, § 501 (a), more commonly known as the "National Defense Exception," provides the Secretary of Defense the ability to waive the Jones Act provisions on navigation or inspection laws when in the interest of national defense. Although the national defense exception provided for in § 501 is a permissible pathway towards obtaining a Jones Act waiver, "[while] the United States does allow a waiver in the interest of national defense; as everyone knows, it is extremely hard to get" (Mendelsohn, p.19, 1991).

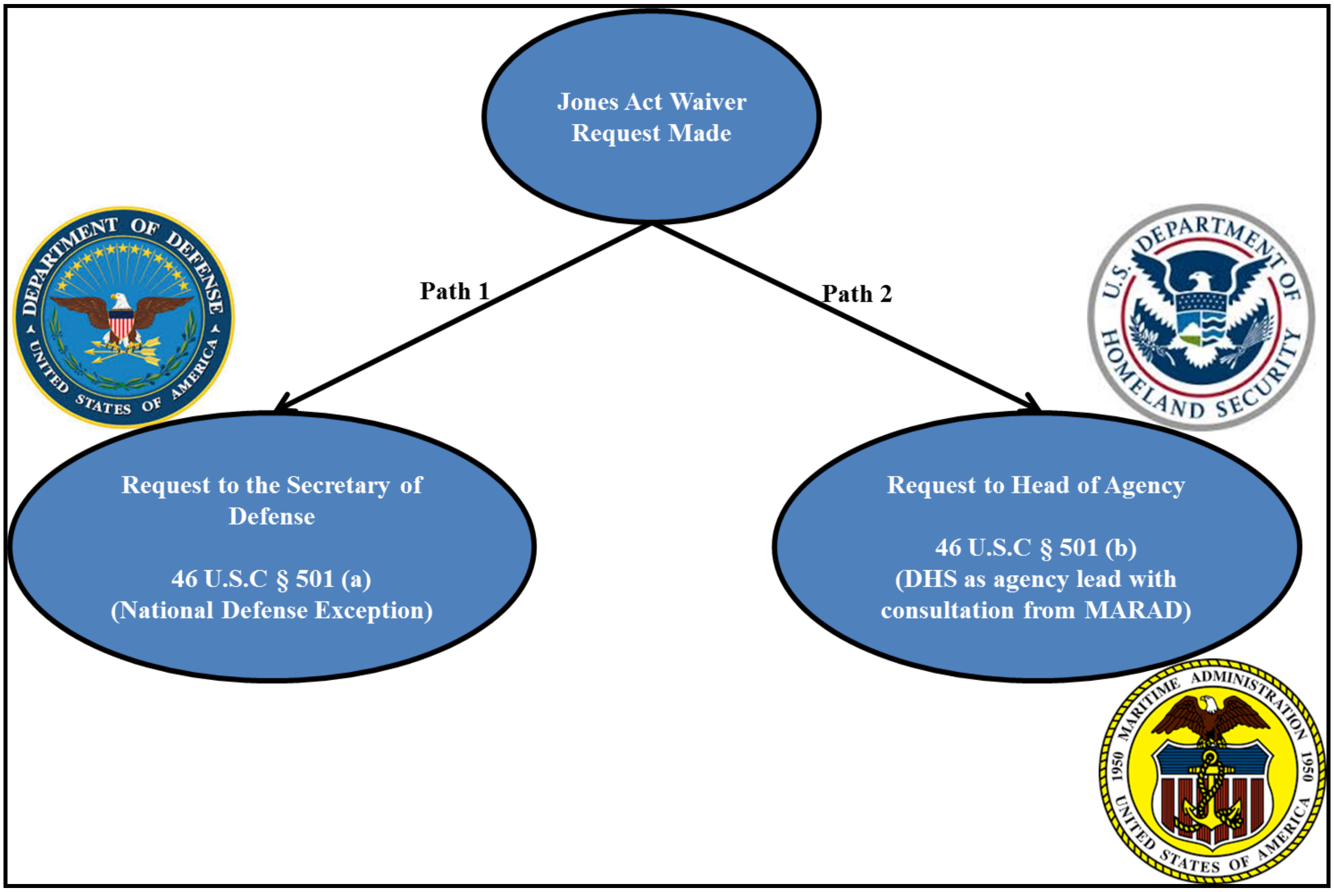

Figure 7.2: Section 501 Jones Act Waiver Pathways
Source*: 46 U.S.C § 501 *et seq. Figure Credit: M. Fialkoff (2017)

An alternative pathway for obtaining a Jones Act waiver states that the Head of an Agency can grant a waiver, again, under the auspice that the activity is in the interest of national defense. Under this alternative pathway, the Head of Agency, usually the Secretary of Homeland Security, in consultation with the Administrator of the Maritime Administration make a determination whether there any U.S flagged vessels could carry out the needed transport, prior to waiving the Jones Act (U.S. Department of Homeland Security, Customs and Border Protection, 2009). Under § 501 (b):

> When the head of an agency responsible for the administration of the navigation or vessel-inspection laws considers it necessary in the interest of national defense, the individual, following a determination by the Maritime Administrator, acting in the Administrator's capacity as Director, National Shipping Authority, of the non-availability of qualified United States flag capacity to meet national defense requirements, may waive compliance with those laws to the extent, in the manner, and on the terms the individual, in consultation with the Administrator, acting in that capacity, prescribes (§ 501 (b), 2017).

Similar to § 501 (a), the primary concern for the DHS Secretary and the MARAD Administrator is whether the waiver will support a national defense interest that cannot be fulfilled by Jones Act vessels. Whereas § 501 (a) vests this authority solely in the Secretary of Defense, § 501 (b) requires the Secretary of Homeland Security to consult the Maritime Administration (MARAD) Administrator to decide whether a waiver should be granted.

In making its determination, the MARAD Administrator "identif[ies] actions that could be taken to enable qualified United States flag capacity to meet national defense requirements (§ 501 (b) (1) (A)). Having decided, the MARAD Administrator shall notify the "Secretary of Transportation, the Committee on Transportation and Infrastructure and the Committee on Armed Services of the House of Representatives and the Committee on Commerce, Science, and Transportation and the Committee on Armed Services of the Senate (§ 501 (b) (3) (A))" within 48 hours. In addition, the MARAD Administrator must also notify the Agency Head who received the Jones Act waiver request. The Secretary of Homeland Security then makes an official decision on whether to grant the waiver or not. Within this process though, there is no information on what actions the MARAD Administrator takes to identify Jones Act eligible vessels or the level of coordination and consultation between DHS and MARAD.

7.4.1 The Jones Act Waiver in Disaster Response

While § 501 exists to provide waiver from the Jones Act provisions, it is widely accepted these waivers are granted only under exceptional circumstances. In instances when § 501 (a) waiver requests were made to the Secretary of Defense, the Department of Defense usually remained silent and the waiver application was denied (Mendelsohn, 1991).

In the context of disaster response, the Government has granted Jones Act waivers sparingly, primarily for transporting petroleum products to and from affected areas. Table 7.1 shows the specific events, the rationale given for the waiver, and disposition of the request. Up until Hurricane Rita, when a natural disaster affected maritime transportation, blanket Jones Act waivers enabled non-Jones Act vessels to engage in coastwise trade. However, after Hurricane Rita, the domestic maritime community voiced opposition to blanket waivers. In 2009, Congress, amended the Jones Act to require the MARAD determination and halted blanket waivers, instead insisting on case-by-case determinations for waiving the Act (Waldron, 2014). In the aftermath of the Libyan conflict and the shortage of oil, Congress required written justification by the Secretary of Homeland Security when granting Jones Act waivers as a way of documenting waiver decisions.

Table 7.1: Recent Jones Act Waiver Requests

Event	Year	Rationale	Disposition of Request
Exxon Valdez	1989	Exxon requested foreign-flag oil skimming barges to assist with clean-up efforts following the vessel Exxon Valdez running aground	**Granted**, provided vessels used to transport waste out of affected area and not as supply vessels
Hurricane Katrina	2005	The storm had a devastating impact on production and transportation of oil, gas, and other energy products	**Granted**
Hurricane Rita	2005	Similar argument made during in the waiver application from Hurricane Sandy	**Granted**, though domestic protest over the availability of vessels. Subsequent waiver requests handed on a case-by-case basis
Libyan Conflict	2011	Release of 30 million barrels of oil from the Strategic Petroleum Reserve (SPR) requiring more vessels to transport product from SPR to domestic locations	**Granted**, though Congress passed subsequent legislation requiring Jones Act waivers provide written justification for request
Hurricane Sandy	2012	Region was devastated from effects of storm, subsequent drop in temperature and reduced oil reserves required vessel deliveries	**Denied** for dry goods movements, but granted for transporting petroleum products to affected areas
Polar Vortex	2014	New Jersey ran low on salt to clear roadways given the harsh winter between 2013-2014	**Denied**, deemed to not be a national defense interest

Source: Waldron (2014).

In two recent Jones Act waiver applications, the Department of Homeland Security denied Jones Act waiver applications for dry goods cargo and salt. In the aftermath of Hurricane Sandy, DHS denied Jones Act waivers for containerized cargo since this cargo movement was not in the interest of national defense (Southworth *et al.* 2014). Although DHS denied waivers for general cargo for Sandy, DHS granted a waiver to transport petroleum products to those states affected by Sandy, especially where home heating fuel supplies became scarce. In the case of Hurricane Sandy, denying the Jones waiver application reduced the ability for modal flexing between modes, putting more pressure on road and rail networks to handle increased freight traffic (Southworth *et al.* 2014). From the legal perspective, the denial of Jones Act waiver for dry goods, but not for petroleum products, highlights the ad hoc nature of decision-making for Jones Act waivers (Flynn, 2015)

Two years after Hurricane Sandy, New Jersey once again was at the center of a Jones Act waiver application. During early 2014, a polar vortex dropped temperatures along the East Coast and increased snow forced New Jersey to deplete its road salt supply earlier than planned. An attempt to transport 40,000 tons of rock salt from Maine to New Jersey stalled because the vessel transporting the salt did not meet the Jones Act requirements (Goldman, 2014). The vessel in question, the *Anastasia S.*, docked in Searsport Maine could have transported the salt to the Port of Newark; however, the vessel's homeport was the Marshall Islands, disqualifying it from engaging in coastwise trade (Spoto and Frassinelli, 2014). New Jersey requested a Jones Act waiver for the *Anastasia S.* but DHS denied the requesting, citing that road salt is not in the interest of national defense (Waldron, 2014). Instead of the $500,000 it would have cost to transport the rock salt on the *Anastasia S.*, New Jersey spent $1.2 million dollars (U.S.) to transport the rock salt on barges (Spoto and Frassinelli, 2014). Although New Jersey blamed the Jones Act, others blamed New Jersey for lack of planning and using the Jones Act as a "scapegoat" to poor winter planning (Waldron, 2014; Spoto and Frassinelli, 2014). The denial of the Jones Act waiver for road salt by DHS is ironic because road salt ensures safe driving conditions on the interstate highway system. One of the original purposes for the construction of the Interstate Highway Systems was to ensure the efficient movement of military vehicles and troops in support of national defense (Weingroff, 2017).

In addition to road salt, the Polar Vortex of 2014 also strained the availability of propane and other oil resources in the Northeast. As resources began to dwindle, oil companies in the Northeast looked for alternative sources to replenish their fuel stocks. While ample propane and other fuel sources were available in Houston, existing pipeline capacity prevented additional fuel to be shipped to the Northeast (Doff and Christie, 2014). Because of the Jones Act, tankers from Texas could not transport propane and other fuel to the Northeast since the vessels did not meet the specifications of the Jones Act (Doff and Christie, 2014). As an alternative, fuel companies looked to resources in Europe to get additional fuel, increasing the fuel costs (Doff and Christie, 2014). Compared to the $673 per ton of propane from Texas, the cost of one ton of propane from Northwest Europe was $785, with additional costs in transportation (Doff and Christie). In September 2014, the Department of Energy Office of Energy Policy and Systems Analysis (EPSA) commissioned a report analyzing U.S. fuel supply, infrastructure, and vulnerabilities (INTEK, 2014). The report concluded that policy changes in the Jones Act waiver process should be considered as a regulatory measure to boost resilience in the energy sector, especially under adverse conditions such as natural disaster or increased fuel consumption (INTEK, 2014).

For all the cases discussed so far, none of the shippers sued the Federal Government because of a denial of a Jones Act waiver. Up until 2015, there was no case law on how the courts viewed the Jones Act waiver process and whether the decisions made were reviewable by the courts. The next section reviews a recent decision on the reviewability of the Jones Act by a court, particularly, the standards applied by agencies in deciding Jones Act waivers and whether such decisions can be reviewed by the court.

7.4.2 The *Furie* Trilogy: Assessing Jones Act Waiver Applications

There is limited case law on Jones Act waivers, particularly in the case of the waiver process and the decision-making by the Secretary of Homeland Security when deciding whether a waiver is appropriate. The most recent decision on agency action relating to the Jones Act waiver process came in 2015 with *Furie Operating Alaska, LLC. v. U.S. Department of Homeland Security*. The case dealt with multiple questions pertaining to the Jones Act, with the court issuing three opinions. The first opinion answering the question of what constituted "final agency action" ("*Furie* I"), the second opinion defining whether an oil rig constituted "merchandise" under the provisions of the Jones Act ("*Furie* II"), and the third opinion determining whether Article III courts could review Jones Act waiver determinations by the Department of Homeland Security ("*Furie* III").

7.4.2.1 "North, to Alaska": The Facts of *Furie* and the *Spartan Rig*

The facts surrounding the *Furie* case arose from the movement of a jack-up rig from Texas to Alaska and the availability of a Jones Act vessel. In 2011, Furie wanted to transport the *Spartan Rig* from the Gulf of Mexico in Texas to Vancouver, British Columbia, using a foreign vessel and then from Vancouver to Cook Inlet, using a U.S. vessel (*Furie* III, 2015). Prior to moving the Spartan Rig, Furie attempted to move another rig, *Tellus*, to Alaska using a foreign vessel. In 2006, when Furie was trying to move *Tellus*, he received a Jones Act waiver from then Secretary of Homeland Security Chertoff. Although he received the waiver, Furie never moved the *Tellus* because of repair and legal issues. Eventually, a foreign party bought *Tellus* and the issue of waiver was moot (*Furie* III, 2015).

In 2010, Furie wanted to move *Spartan Rig* from Texas to Alaska for natural gas exploration. Encountering similar issues of American vessel availability, Furie planned to move the *Spartan Rig* using a foreign vessel. When Furie applied for another Jones Act waiver, this time under Secretary Napolitano, he did not receive a response to his waiver request. Furie informed Customs and Border Protection that he was going to move *Spartan Rig* using the former waiver given under Secretary Chertoff (*Furie* III, 2015). CBP informed Furie that the waiver was no longer valid and he would face penalties if he moved *Spartan Rig* using the old waiver (*Furie* III, 2015).

In 2011, Furie requested a new waiver from Secretary Napolitano. Secretary Napolitano denied his waiver request because MARAD determined there was a U.S vessel capable of transporting the *Spartan Rig* from Texas to Alaska. Furie believed the MARAD assessment was incorrect and began to move the *Spartan Rig* from Texas (*Furie* III, 2015). Meanwhile, MARAD did revise its determination and concluded that no American vessels were available until October, prompting Furie to request a waiver on an expedited basis (*Furie* III, 2015). Again, Secretary Napolitano denied the waiver request because the request neither met the national defense exception nor did the Department of Defense or the Department of Energy support the need for a waiver of the *Spartan Rig* (*Furie* III, 2015). Although DHS tried to work with Furie, the voyage continued, with the vessel and *Spartan Rig* reaching Cook Inlet in the middle of August 2011. On October 13, 2011, CBP sent Furie a notice of violation for the foreign vessel leg of the trip, assessing Furie a penalty of $15 million, the full value of the *Spartan Rig*. Furie refused to pay the penalty and instead filed suit in Federal District Court of Alaska (*Furie* III, 2015).

7.4.2.2 Reviewability of Jones Act Waiver Decisions

With respect to the Jones Act waiver, Furie made two claims: (1) that the Secretary failed to make an independent decision on the waiver and her decision was arbitrary, capricious, and an abuse of discretion under the Administrative Procedures Act (APA) and (2) the fact that Secretary Chertoff granted a waiver and Secretary Napolitano did not without explanation illustrated arbitrary and capricious behavior as well as an abuse of decision. For both claims, the court ruled in favor of the Secretary of Homeland Security that her decision was unreviewable under the APA and her decision was committed to the discretion of the agency.

Furie's first argument claimed that in denying his request for a waiver under 46 U.S.C. § 501 (b), the Secretary failed to exercise independent judgment and relied solely on the advice provided by the Departments of Defense and Energy. To rebut this argument, DHS argued that the under the Administrative Procedure Act (APA), the decision by the Secretary is "an action committed solely to agency discretion because it involves a purely discretionary decision about national defense and statutory enforcement and is thus unreviewable under § 701 (a)(2) of the APA" (*Furie* III, p.5, 2015).

Under the APA, a person "adversely affected or aggrieved" by final agency action can obtain judicial review of said action (*Furie* III, p.5, 2015). In general, the APA has a presumption of judicial review, unless the action is committed to the agency by the discretion of law, and therefore is unreviewable. According to the district court, "[a]gency action is deemed committed to agency direction by law 'in those rare instances where statutes are drawn in such broad terms that in a given case, there is no law to apply'" (*Furie* III, p.5, 2015). In reviewing the provisions of the Jones Act waiver process, the court determined that the decision on Jones Act waivers fit within "those rare instances" where the decision is solely that of the Secretary. The operative language in 46 U.S.C. § 501 (b) provides that the Secretary *may* grant a waiver if she "considers it necessary in the interest of national defense" after MARAD determines a U.S. vessel is not available.

The district court's analysis focused on the national defense language and the lack of meaningful standard with 46 U.S.C. § 501 (b) to apply for the Secretary's decision. First, the court made clear that in issues of national defense, the courts have had a long history of avoiding interference in areas of national defense. As this is an Executive Branch area, the courts did not want to interfere in these sensitive policy areas and substitute their own judgment for that of an Executive Branch officer. Second, the court noted that Furie failed to provide any statutory provision that could be a "meaningful standard" for the court to apply in reviewing Secretary Napolitano's refusal to grant the waiver.

Having determined the waiver decision to be committed to agency discretion, the court turned to Furie's other argument that the DHS Secretary improperly delegated her authority for making the waiver decision to the Departments of Defense and Energy. The court determined that Secretary Napolitano could request internal guidance from other Departments, including the Department of Defense and or Energy when making her determination. Although Furie claimed such a request violated the process established in 46 U.S.C. § 501 (b), the court was un-persuaded, stating that neither Secretary Napolitano nor the agencies she consulted attempted to side-step internal procedures or co-opt the process, rather sought more guidance from competent agencies. The court went as far as to articulate that such processes yield decisions that courts "have zealously avoided trying to second guess" (*Furie* III, p.7, 2015).

7.5 Critique of the Jones Act Waiver Process

The case of *Furie*, particularly the opinion for *Furie* III illustrated the problem that there is no meaningful standard or guidance to review Jones Act waiver decisions. Although the *Furie* case had nothing to do with disaster response, the district court recognized that the language §

501 (b) provides no guidance or standard for making Jones Act waiver determinations. While the court held that such determinations were committed to the agency, it presents a problem for shippers trying to plan in the aftermath of a disruption. Within the *Furie* opinion, the court was careful to outline that given the national defense sensitivities involved in the § 501 (b) waiver process, the courts have taken a hands-off approach to interfering in those types of decisions. Furie tried to argue that "national defense," particularly in his case of moving the *Spartan Rig* from Texas to Alaska was unfairly interpreted to mean a national defense emergency and therefore felt that such treatment was unfair. The district held that for issues of national defense, courts are hesitant to interfere as such decisions are best suited for the Executive Branch, not the Judiciary.

Furie's disposition raises similar issues to what Flynn (2015) critiqued in the aftermath of Hurricane Sandy and the Jones Act waiver process in that situation. While the Jones Act was eventually waived for vessels carrying petroleum and other oil-related products for the Mid-Atlantic, dry goods and container cargoes were diverted to other ports, with no waivers being granted (Flynn, 2015). This selectivity in choosing which commodities deserve waiver and which do not led to an ad hoc process, viewed in some regards as a barrier to freight recovery (Flynn, 2015; Southworth *et al.* (2014)). Although Congress amended the Jones Act to include MARAD in the determination of Jones Act waivers, there is limited guidance as to what MARAD identifies as Jones Act eligible vessels. As reflected in the facts of *Furie*, Furie was able to receive a waiver from Secretary Chertoff, but was denied a waiver under Secretary Napolitano. This absence in consistent standard or guidance for what goes into a Jones Act waiver determination creates uncertainty for shippers.

The decision in *Furie* and the critique leveled by Flynn (2015) and Southworth *et al.* (2014) lend themselves to a larger, more theoretical question discussed by Ruhl (1996). Do doctrines such as "committed to agency discretion" and the lack of "meaningful standards" cause the law to detract from resilience insofar as the discretion is based on an agency head with limited legislative guidance? Ruhl (1996) would argue yes, that the vagaries of a statute, Jones Act or otherwise, creates uncertainty, particularly as agency heads change and policy directives ebb and flow with the incoming and outgoing administrators. With no legislative guidance, the agencies make decisions based on policy expertise, with courts deferring based on separation of powers.

Furie and the Jones Act waiver process is different in that the § 501 (b) decision-making is made by the DHS Secretary, with input given by MARAD and other competent agencies. In *Furie*, Secretary Napolitano relied on input from the Department of Energy and the Department of Defense to deny Furie his waiver. In the case of Hurricane Sandy, the decision was for Secretary Napolitano with input from the MARAD administrator. *Furie's* opinion did not look at the dynamics or relationships between agencies that are delegated decision-making power. Whereas the district court held that DHS did not side-step internal processes when it consulted the Department of Energy and the Department of Defense, the court did not describe what those internal dynamics looked like, or how they interacted to arrive at their decision. Again, the district court's opinion in *Furie* held more broadly that the court should not interfere within the decision-making process on policy matters of the agency, but the opinion does leave open the question as to how agencies cooperate or coordinate in decision-making.

7.6 Proposed Reforms for the Jones Act Waiver Process

Considering the ad hoc nature of the Jones Act waiver decisions and its perceived impact on freight transportation, what remedies are available to "fix" the Jones Act waiver process? This question assumes fundamentally that the Jones Act waiver process is broken or a barrier to resilience within the maritime transportation system and for that matter, the greater freight transportation network. In contrast to calls for outright repeal and reform of the statute overall, the fundamental question at issue is what can be done to make the waiver process facilitate more resilient behavior in the context of freight mobility.

7.6.1 Remove Vagary: Legislative Standards for Jones Act Waivers

One potential reform would be to have Congress redraft the waiver provisions to include language that provides meaningful standards by which courts could review Jones Act waiver decisions. This reform would track with the reforms advocated by Ruhl (1996) more broadly with respect to Administrative Agencies and the enabling legislation that provide them power. This remedy would require reopening the debate on the Jones Act. The danger in this endeavor is two-fold; first, in the current political climate, a discussion on reforming the Jones Act waiver process is impossible. In 2015, Senator John McCain introduced the Energy Policy Modernization Act of 2015 to change portions of the Jones Act (Hansen, 2016). The attempt by Senator McCain was his third attempt since 2010 to amend the Jones Act, with all three tries meeting limited support from Congress (Hansen, 2016). The current political climate in

Washington D.C. suggests that changing the Jones Act waiver process would meet resistance from the domestic shipping industry and other senators.

Second, would such a discussion regarding the Jones Act waiver process be one that Congress would be interested in having. In the early 1990s, a recommendation was made that the waiver process undergo administrative change, but such matters were subsequently dropped (Mendelsohn 1991). Events of the last decade, including Hurricanes Katrina, Rita, and Sandy highlight a new perspective for understanding the need for the Jones Act waiver, which could enable Congress to review the provision in isolation of the larger meaning of the Statute. Essentially, Congress could not reform the Jones Act and the restriction on short sea shipping entirely, but explore a legislative carve-out for those situations where disaster response calls for Jones Act waivers.

One suggestion would be to link the national defense language to other statutes, particularly those in disaster response. In the case of the Jones Act, if the term national defense read similarly to its definition in the Stafford Act, national defense would include natural disaster. However, the waiver provisions of the Jones Act have never been read co-extensively with other statutes, including the Stafford Act. This is because the conditions that activate the provisions of the Stafford Act (a natural disaster event) are different than those involving the Jones Act waiver (national defense or exception by an Agency Head); reading the terms similarly between the two Statutes would prove more problematic.

More broadly, increased Congressional intervention would vest more power back in Congress and remove perceived vagueness from the Department of Defense and the Department of Homeland Security. From Ruhl's perspective, Congressional intervention would indicate a clawing back of power away from these agencies and provide more clarity and certainty. Insofar as this claw-back increases certainty and clarity, it also creates rigidity and less flexibility for adaptation and robustness in the systems they govern (Arnold and Gunderson, 2013). Would Congressional intervention in redrafting the provisions for Jones Act waivers enable more adaptive governance in the area or further contribute to a mal-adaptive state that cannot adapt to conditions because of linear thinking based in statutory language (Arnold and Gunderson, 2013)? The problem then lies in whether such Congressional action would be viewed as attacking the core of the Jones Act and running-up against institutionally ingrained norms regarding the import of the Statute in the maritime economy of the U.S.

7.6.2 Regulatory Reforms: Unilateral Rulemaking and Agency Coordination

If Congressional intervention is not feasible given the current political climate or the concern that revision would get lost in a larger discussion on repeal or reform of the Jones Act more generally, could greater agency coordination lend itself to reforming the process? Under § 501 (b) of the waiver provisions, the Department of Homeland Security is vested power in determining Jones Act waivers, but must consult with the Maritime Administration and other agencies. MARAD's determination focuses on the availability of U.S. vessels and the national defense exception for Jones Act waivers, but as evidenced in *Furie*, other agencies are involved.

In terms of regulatory reform, the first possible reform would be to have the Department of Defense develop guidelines for making Jones Act determinations. Under § 501 (a) of Title 46, the Department of Defense is vested with making Jones Act waiver determinations. Unlike § 501 (b) where such determinations are made by DHS in consultation with MARAD, DOD can make such decisions unilaterally. Under this reform, the Department of Defense could either provide policy guidance, or enter into formal rulemaking to promulgate rules and procedures for handling Jones Act waiver applications. In the first instance, such policy guidance is merely guidance and is subject to revision with each new Secretary of Defense, similar to the situation Furie encountered with the Secretary Chertoff and Secretary Napolitano. In the latter instance, formal rulemaking ensures certainty and provides formal guidance and standards for evaluating Jones Act waiver applications. This reform also assumes that Jones Act waivers are a high priority within the DOD. Although delegated responsibility for making Jones Act waiver determinations, historically, the DOD usually denies such applications as not meeting the national defense exemption (Mendelsohn, 1991).

In the alternative to unilateral action by the DOD, another reform would be for the Department of Homeland Security and MARAD to engage in further agency coordination to develop clear standards for evaluating Jones Act waiver applications. In the aftermath of Hurricane Katrina and Rita Jones Act waivers determinations, it was determined that the best course of action for Jones Act waivers was to a make decision on a case-by-case basis (Waldron, 2014). Furthermore, the events in Libya prompted Congress to instruct the Department of Homeland Security to further consult other agencies to better coordinate waivers. While Institutional Theory highlights the reasons for administrative fragmentation, recent research in the area of administrative arrangements involving multiple agencies yields possible tools for regulating "shared regulatory space." Examples of such tools are illustrated in Table 7.2 (Freeman and Rossi, 2011).

Table 7.2: Strategies for Interagency Coordination

Strategy	**Description**
Agency Consultation	Agencies talk with one another for areas of policy or statutory overlap. Depending on provisions of the statute, consultation may be discretionary or mandatory.
Inter-agency Agreements (Memorandum of Understanding)	Agencies enter formal type agreements to work together in policy spaces based on requirements under the statute.
Joint Policymaking	Agencies are equally involved in the rulemaking process. Unclear as to the effect on the level of deference granted in this arrangement under *Chevron*.
Presidential Management	Presidential management of the agencies using tools of presidential councils or regulatory review.

Source: Freeman and Rossi (2011)

In the case of the Jones Act waiver process, the most feasible strategy for implementation from Table 7.2 would be for further Agency Consultation between DHS and MARAD. Agency Consultation provides low level interaction between the agencies and acknowledges the relationship between the agency making the final decision on the waiver and those agencies provide guidance and information (Freeman and Rossi, 2011). While there are no regulatory provisions currently in place for Jones Act Waiver procedures, should Department of Homeland Security and MARAD decide to promulgate regulations regarding the waiver process, another strategy for increased cooperation would be Joint Policymaking, where the Department of Homeland Security and MARAD promulgate regulations on waiver procedures together. The challenge in this strategy would be determining the level of deference afforded these regulations (Freeman and Rossi, 2011). If multiple agencies are involved in rulemaking, does this 'double" the level of *Chevron* deference given multiple agency involvement or does it "halve" the deference as it would illustrate that multiple agencies are trying to promulgate regulations which are not within the statutory language of the Act (Freeman and Rossi, 2011). In *Rapaport v. U.S. Department of Treasury* (1995), Judge Rogers in his concurring opinion argued "when more than one agency has authority to interpret a statute, such deference should be scrutinized but not jettisoned because one agency has *a priori* interpretation over the other" (*Rapaport*, 1995). However, the "cluttering" of the regulatory space with multiple agencies promulgating joint regulations leads to further redundancy and ossification of institutional structures, potentially leading to less robust ability to react to an emerging situation (Freeman and Rossi, 2011; Arnold and Gunderson, 2013).

7.6.3 The Do-Nothing Option

Although recent research focused on the Jones Act waiver process and the challenges it presents under certain circumstances, these events are isolated. Critique of the Jones Act waiver process is limited to specific events, with the *Furie* trilogy being the only case where the issue of the Jones Act waiver arose. Why tinker with something that has not generated much treatment by the courts and from the perspective of MARAD, has limited application? The concern in making any chances to the Jones Act waiver process is the fear that opening the Jones Act for review can lead to a "Pandora's box" of horrors within the domestic shipping community. When Leback and McConnell wrote their critique of the Jones Act in 1983, the review met with both constructive criticism, but also outright hostility to any suggestions in change. In the recent confirmation hearing for Secretary of Transportation Elaine Chao, Senator Brian Schatz, a Democrat from Hawaii focused on the import of the Jones Act and asked for the commitment of the Secretary to ensure the preservation of the Jones Act as it related to domestic U.S. shipping (Transportation Secretary Confirmation Hearing, 2017).

While critiqued by some as hampering disaster recovery, another prevailing opinion is increasing Jones Act waivers to dry cargoes is a "nuclear option," that has rarely been considered. Regardless of Congressional intervention of regulatory coordination, the current arrangement for Jones Act waivers are tailored to one commodity, petroleum products (Waldron, 2014). Opening the waiver process to other commodities can lead to increased application for waiver and create confusion on the availability of the waiver. In the case of Hurricane Rita, when a Jones Act waiver was granted in the aftermath of that disaster, the domestic shipping community was adamant that U.S. vessels were available and such a waiver wasn't appropriate (Waldron, 2014).

7.7 Summary

In trying to understand the impact of the Jones Act on freight transportation resilience, understanding the role of the Jones Act and its waiver provision illustrate the challenge of reconciling the way the law functions with the laws impact on constituent systems it governs. In the case of the Jones Act waiver process, the lack of guidance from the agencies and the absence of standards for assessing waiver applications hamper recovery and acts as a barrier to developing resilient behaviors. Towards the end of the chapter, recommendations for reform focused on Congressional intervention or regulatory reforms. Given the current political climate, regulatory reform, especially with greater agency coordination between the Department of Homeland Security and the Maritime Administration, seems to be the best possible option.

Overall, this chapter illustrated that systems, be them legal, administrative, or transportation are interdependent on one another, but also independently from one another. Recognizing law as a distinct system highlights the System of Systems framework in linking the legal system with an infrastructure system, such as transportation. Thus, decisions on how a statute is administered can lead to the restriction of a modal option and pose a barrier for recovery. But within the system that causes the restriction, challenges to administration can themselves lead to greater changes that go beyond whether a vessel can move from Norfolk and New York, to what is the proper role of the legislature, the courts, and the administrative agencies in making decisions that affect vessels and freight.

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Chapter 8: Conclusions and Future Research

8.1 Putting in to Port: Summary of the Research Presented

The over-arching question this dissertation sought to address was, to what extent law and policy can affect operations in a networked infrastructure in the aftermath of a disruptive event. This research used a case study to evaluate this question: what is the impact of the Jones Act on the freight transportation network in the aftermath of Hurricane Sandy. Relaxing the Jones Act would change truck traffic in the area surrounding Norfolk International Terminal, but not have regional impacts for rail or truck traffic.

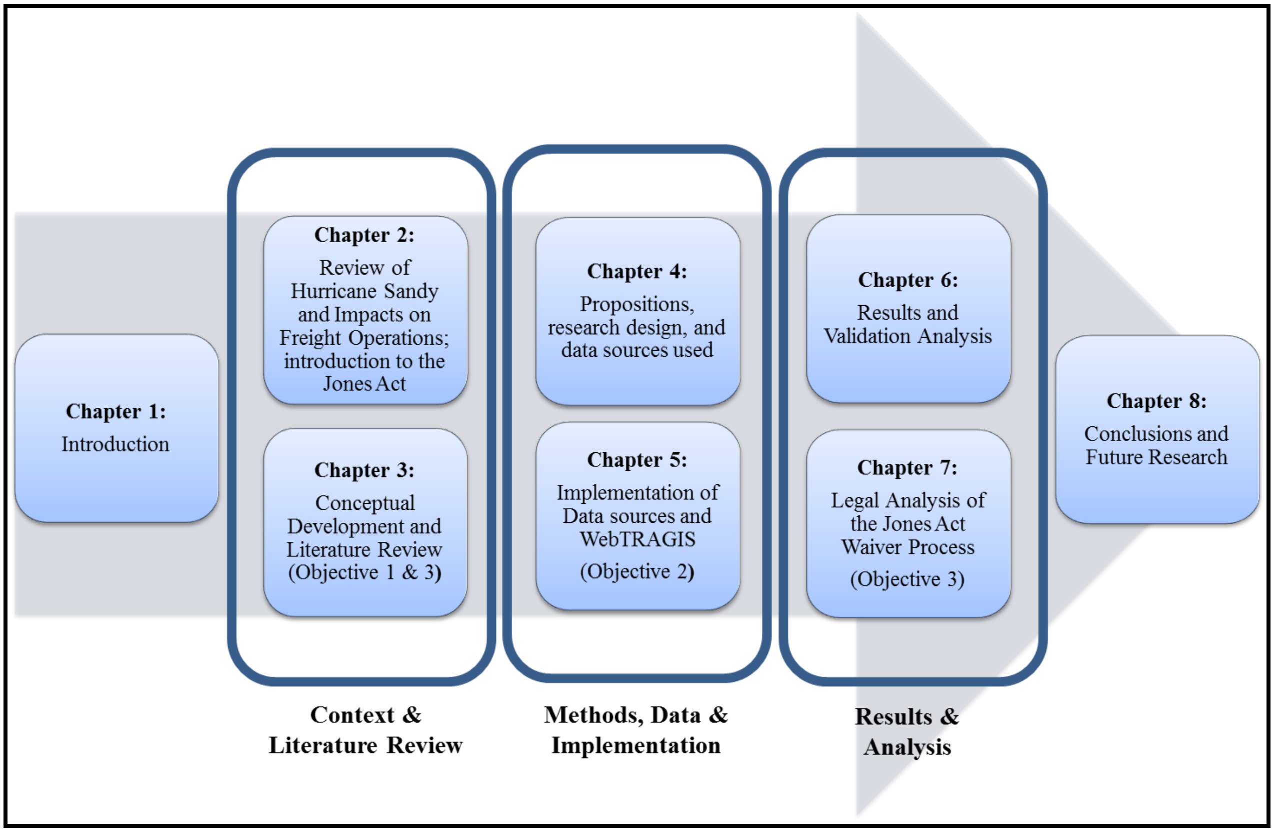

Figure 8.1: Structure of the Dissertation Revisited
Credit: M. Fialkoff (2017)

Figure 8.1 summarizes the structure of the dissertation. Chapter 2 introduced the case of Hurricane Sandy, its effects on pieces of infrastructure and the freight transportation network. Chapter 2 also briefly introduced the Jones Act, the restriction on foreign vessels moving between two coastwise points in the United States, and critique of the Jones Act as a barrier to freight flow recovery in the aftermath of Hurricane Sandy. Given the complex, interacting systems involved in analyzing how a law influences a physical system, Chapter 3 provided a framework with which to approach answering this question. In contrast to the systems view of transportation, this dissertation used a System of Systems framework because it recognizes the independence of interacting systems and the behaviors leading to as resilience.

Chapters 4 and 5 developed the research questions, hypotheses, and research design considerations in studying the Jones Act and its effect on the freight transportation network after Hurricane Sandy. Chapter 4 introduced the use of a diversion analysis to study freight flow and introduced the datasets used in this research, the Freight Analysis Framework and the Confidential Carload Waybill Sample. Chapter 5 discussed the procedures for flowing transportation over networks. Chapter 6 presented the results from the three scenarios developed to study the effect of the Jones Act. From these results, relaxing the Jones Act did not a indicate a significant impact on traffic flow because of freight diversion for this case study. For highway, there was an 8% - 9% decrease in truck traffic on roads surrounding Norfolk International Terminal (NIT) with the Jones Act relaxed compared to the Act not being waived. For railway, there was no change in rail traffic between the three scenarios developed. From these results, this would indicate that the modal flexing developed by Southworth *et al.* (2014) would not add to recovery efforts. The effect of relaxing the Jones Act would be localized to the traffic surrounding the port receiving diverted freight.

While Chapter 6 addressed the impact of the Jones Act on transportation networks, Chapter 7 looked inward at the statutory and regulatory framework of the Jones Act, particularly the processes involved with obtaining a Jones Act waiver. One of the critiques of the Jones Act was the ad hoc nature of the process in obtaining a waiver and the uncertainty involving who is eligible for a waiver and who is not (Flynn, 2015). Chapter 7 pointed out that a fundamental problem with current Jones Act and cabotage jurisprudence is the incorrect interpretation of the statute and its provisions by policymakers and the courts. The Jones Act was enacted to ensure vessels built in the aftermath of World War I would be put to use and ensure a continued merchant marine fleet. The Act itself was neither a protectionist policy, nor a national security/defense policy. Rather, the Act was a means for the government to recover its investment in shipbuilding as part of the war effort.

Focusing on the waiver process, there is limited case law on Jones Act waivers. The recent decision in *Furie* held that decisions made by the Department of Homeland Security (DHS) on Jones Act waiver applications are immune from Article III review. While the decision to waiver the Jones Act is the "nuclear option" in maritime transportation because of previous impacts of waiving the Act, *Furie* provides an opportunity to reflect on how coordination and communication between relevant agencies could enable greater clarity and uniformity in responding to waiver requests.

8.2 Summary of Research Objectives, Questions, and Findings

A summary of the objectives, questions, and findings of this research are summarized in Table 8.1.

Table 8.1: Summary of Research Problem, Objectives, Questions, Findings, and Contributions

Problem	Research Objective	Research Question	Research Finding	Contribution
1. There is limited research in the area of law and its relationship to critical infrastructure	Establish a conceptual and theoretical framework to study the relationship between law and freight transportation	What effect does the imposition and subsequent relaxation of the Jones Act have on freight transportation networks experiencing disruption?	The relaxation of the Jones Act has a localized effect on freight transportation networks, with no increase in rail traffic and limited truck traffic decrease	Answers question as to the effect of a particular law on critical infrastructure resilience; provides framework for studying policy questions related to law and critical infrastructure resilience
2. Previous research has critiqued the effect of a particular law such as the Jones Act as a barrier to resilience but no study presents results as to the effect of the Statute on transportation networks (exogenous issue)	Apply novel quantitative techniques to study the effect of law on transportation networks experiencing disruptions	How can existing transportation data be used to study policy-based interventions on transportation networks?	Conversion of the Confidential Carload Waybill Sample to geo-spatially enabled routes and use of the Freight Analysis Framework on a transportation routing platform provided an approach to study the effects of a law on a transportation network	For railroad freight analysis, a novel, interoperable process has been demonstrated for the purpose of future transportation policy research
3. The Jones Act waiver process has been understudied from the perspective of critical infrastructure resilience and has been critiqued as a barrier to resilience (endogenous issue)	Evaluate existing statutory and regulatory processes as they relate to the Jones Act waiver process, providing a critique of existing regulatory frameworks and looking forward to alternative legal approaches to handling waiver requests	What policy recommendations are available to reform the Jones Act and the current legal environment to short sea shipping in the United States for disruptive events?	While the recent court decision in *Furie* frustrates the availability of the Jones Act waiver and its review by Article III courts, current inter-agency collaboration and consultation can be strengthened to ensure greater inter-agency involvement in decision-making	Fills a gap in regulatory understanding of the Jones Act waiver process and provides policy suggestions for dealing with Jones Act waivers in disruptive situations

Credit: M. Fialkoff (2017)

8.2.1 Using System of Systems to Study Law and Transportation

In addressing the first research problem identified in Table 8.1, the Critical Infrastructure Protection literature discussed how law and policy are "environmental factors" that infrastructure systems address with (Rinaldi, Peerenboom, and Kelly, 2001). This view of the law and policy as "environmental factors" ignored the premise that law and policy are themselves systems. Given the complexity of interacting systems, the use of Systems Thinking was inadequate for understanding and providing a conceptual framework for studying questions on the interaction between law and networked infrastructure. With recent developments in the System of Systems literature that acknowledges the independence and emergent behaviors that result from interacting systems, a System of Systems framework was developed for this study, as illustrated in Figure 8.2.

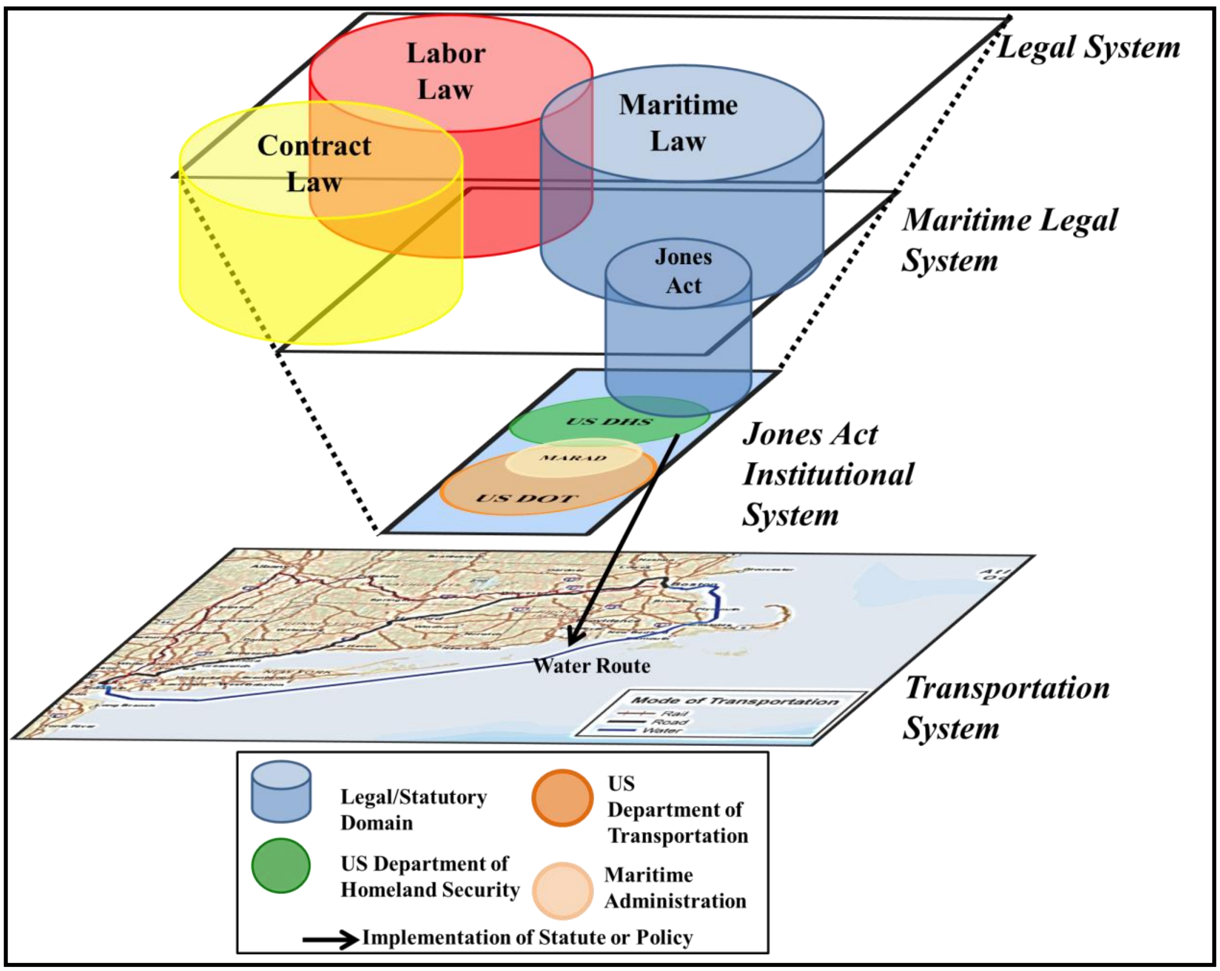

Figure 8.2: System of Systems Framework Developed for Studying the Relationship between Law and Networked Infrastructure
Credit: M. Fialkoff (2017)

Overall, this research externalized law and policy and illustrated how law and policy are systems unto themselves that act independent of transportation systems. Applying a System of Systems framework provided a platform to represent the interactions between the legal system, the institutional system that implements the law, and how such implementation impacts the transportation system it governs. In Chapter 6, the focus was on the interaction between the institutional system and the transportation system. In Chapter 7, the emphasis was on the relationship between the law and its subsequent implementation in the institutional system.

Although the results from Chapter 6 indicated that relaxing the Jones Act would not adversely or positively affect the highway or railway networks handling diverted traffic, the use of a System of Systems framework provided a platform to analyze interacting systems with law and policy as an explicit system. Albeit one example, the this research provides a framework for applying a System of Systems approach to other statutes and regulations to study their relationship with the infrastructure systems they govern.

8.2.2 Application of Techniques for Analyzing Rail Freight Flow

Chapter 3 and chapter 4 introduced diversion analysis for freight transportation networks. Previous research highlighted the use of GIS in analyzing freight diversion; however, previous research did not study how a particular law or policy affected freight movement (Stich, 2014). Using the Freight Analysis Framework, the Confidential Carload Waybill Sample, networks developed by Oak Ridge National Laboratory (ORNL), and TRAGIS, this research conducted a diversion analysis focusing on the effect of a particular law on the transportation network.

Question 2 asked how existing transportation data can be leveraged to study policy-based questions for freight transportation and diversion analysis. The process described in Chapter 5 highlights the integration of transportation data with analytical networks to conduct policy analysis. Although the ORNL networks and TRAGIS were selected as the tools for this analysis, the processes described in Chapter 5 are translatable across different networks, datasets, and analysis platforms.

8.2.3 A Better Understanding of the Jones Act Waiver Process

Both Flynn (2015) and Southworth *et al.* (2014) critiqued the Jones Act as a barrier to freight transportation recovery in the aftermath of Hurricane Sandy. Whereas Southworth *et al.* focused on the operational restrictions of Jones Act, Flynn (2015) critiqued the regulatory process involved in obtaining a waiver, rather than its outward effect on the transportation network.

While the Jones Act waiver process has garnered limited legal research, Flynn's critique provided an opportunity to understand the waiver process, its jurisprudence, and the administrative challenges associated with relaxing the Jones Act. With the recent decision in *Furie*, holding that Jones Act waiver decisions are unreviewable by Article III courts, this dissertation analyzed whether such a holding was consistent with Flynn's (2015) assertion that the ad hoc nature of the waiver process was a barrier to resilience. What became clear was that the interpretation of the Jones Act itself has gone astray. The decision to waive the Jones Act is not taken lightly, rather goes through an inter-agency process that can be improved to provide for less ad hoc decision-making and more uniform outcomes, applying the research by Freeman and Rossi (2011).

At no point in this dissertation was the goal to advocate the repeal of the Jones Act; the goal was to externalize the legal and policy system in an evaluation of its impact on the transportation system using a readily available case study. During this process, a nuanced review of a particular provision, the waiver of the Jones Act, was conducted to put the analysis in context. The contribution of this analysis on Jones Act jurisprudence provides maritime policy-makers with a critique of the existing process, including recommendations for more robust inter-agency involvement in decisions relating to Jones Act waivers, particularly in cases involving general freight and the regulatory implications of such waivers.

8.3 Implications of Research Findings

These research findings have implications for transportation practitioners and those who study freight transportation planning, critical infrastructure resilience, and the law. In particular, this research is unique in the highly contextualized set of facts that supported the analysis.

8.3.1 Implications for Transportation Planning in Practice

In reviewing the literature on freight diversion analysis, this is the first type of analysis where the Jones Act was analyzed as to its impact on general cargo diversion. While previous disasters either waived the Jones Act in its entirety or not at all, the results and findings within this research indicate that relaxing the Jones Act, while appearing to be a promising strategy in the event of a disruptive event, did not indicate a large impact on performance of the network.

In the most recent call for proposals by the National Cooperative Freight Research Program (NCFRP) by the Transportation Research Board (TRB), the question of regulatory factors for studying freight resilience was selected by the reviewing committee as important (Rogers, 2016). Insofar as this research illustrates how a law such as the Jones Act affects freight transportation resilience, it is a first step towards a better understanding the institutional and regulatory actors involved in freight transportation and how such actors can better coordinate in the aftermath of a disruptive vent, like Hurricane Sandy.

In the realm of Jones Act jurisprudence, this research does not advocate for the repeal of the Jones Act. As recently as the confirmation of Secretary of Transportation Elaine Chao, the importance of the Jones Act cannot be understated. This aspect of the research increase understanding of the provisions within the Jones Act, including understanding why the Jones Act was originally enacted and learn how agencies involved with the implementation of the Statute can better coordinate to ensure more uniform decisions, especially in the realm of law.

8.3.2 Implications for Understanding Critical Infrastructure Protection

On a conceptual level, this research introduces a framework to study the impact of law and policy on critical infrastructure. By applying a System of Systems framework to understanding critical infrastructure, this research externalizes the law and policy domains and acknowledges the independence that law and policy bring with respect to infrastructure governance.

For the framework applied in this research, the use of the System of Systems illustrates the evolutionary view associated with studying transportation as a System. The System of Systems approach acknowledges the autonomy of systems, the connectivity and diversity of such constituent systems, and the behaviors that result when these independent systems interact that result in emergent behaviors that can lead to resilience within a system. This complexity requires more nuance and specificity with how actors interact beyond traditional general Systems Thinking.

8.4 "Fail Again, Fail Better": Lessons Learned and Limitations

Many lessons were learned related to the use of data for freight transportation analysis and the importance of context as it relates to conducting analyses. First, while the process and framework used to study the Jones Act and its impact on freight movement during Hurricane Sandy can be applied to other events or statutes, the results reported here should not be generalized to claim that under any disruptive event, the Jones Act should not be waived. In Hurricane Sandy, the Norfolk International Terminal was able to handle the excess container traffic because of the traffic pattern with Norfolk being an export facility where excess vehicles were available to transport extra containers resulting from diversion from New York (Luebbers, 2016). If a disruption occurred where an import facility with limited vehicle availability was receiving diverted cargo, the impact may be greater than was reported at NIT. The highly contextualized nature of the commodity being studied, the ports affected (import vs. export), and the availability of vehicles lends itself to the conclusions drawn in this case, but may not be the case in other examples (Hurricane Katrina or Hurricane Rita).

8.4.1 Passenger Traffic and Freight Traffic Data Limitations

In addition to the lessons learned, there were limitations that were identified over the course of this research, some common to studying freight transportation generally and some specific to the tools selected to study the problem. This research focused on the impact of the Jones Act on freight movement both on the highway and railway network. On both networks, freight is not the only thing moving; both networks are a mix of passenger and freight traffic. The results reported only show the impact on rail traffic based off the Confidential Carload Waybill Sample and the Freight Analysis Framework. Particularly in the case of the railway traffic analysis, the traffic analysis does not account for the effect of commuter rail on rail traffic, particularly in the Northeast Corridor

In the case of the highway analysis, the problem had less to do with data availability and more to do with network conflation. Each state Department of Transportation has varying levels of information relating to traffic counts and a geographic road network that for the analysis conducted would need to be "stitched" together. In contrast, the ORNL highway network is a "complete" network for the United States. The ORNL network is "complete" only for major interstates, State Highways, and U.S. routes.

8.4.2 Shortest Path Solution as Assignment Methodology

For the freight analysis conducted in this dissertation, both the highway and railway network assignment used the shortest path solution. Although previous work does allow for a shortest path assignment, especially in cases where freight is diverted and the goal is to get the freight to its destination as fast as possible (distance wise or time wise). It should be acknowledged that the results reported here would be different if a different assignment methodology is used.

8.5 Atop the Forecastle Looking Ahead: Future Research

Despite the limitations discussed, the research conducted presents future research opportunities for further investigation into the impact of disruptions on freight transportation networks. Specifically, the proposed future research changes the scale from a macro approach taken in this research to a more localized approach. Future research could focus on individual port facilities affected by disruptions and the local networks surrounding the affected facility.

8.5.1 Further Study of Transportation Impacts Surrounding Norfolk

In the case of Hurricane Sandy, many containers bound for New York were diverted to the Norfolk International Terminal (NIT) for subsequent distribution into the highway and railway networks. From the research reported here, there was an increase in truck traffic along specific portions of the highway network, particularly those roads in the immediate vicinity of NIT. Within Scenarios Two and Three, increased truck traffic was seen on Terminal Road, Interstate 64 Northbound approaching the Hampton Roads Bridge-Tunnel, U.S. Route 13 approaching the Chesapeake Bay Bridge-Tunnel, and Interstate 64 southbound heading west. However, when examining the network beyond these highway segments, particularly when moving further away from Norfolk, the scenarios illustrate that traffic flow does not change appreciably, if at all, even with the increased truck traffic leaving from Norfolk. Even with the shortest path assignment methodology, the increase on I-95 does not indicate a significant increase that would cause congestion or bottlenecks at a macro level.

For this research, a macro-level view was used, consistent with work by Crainic and Laporte (1997) for studying policy interventions and their effect on transportation networks. From the results presented, potential future research would be to move from a macro-level analysis to a local analysis, focusing on the local highway and railway network surrounding a port facility. In this case, the micro-level analysis would focus on the highway and railway network surrounding NIT. If a micro-simulation of the local road and rail traffic was undertaken, TRAGIS would not be an appropriate tool for conducting the analysis. Tools such as Rail Traffic Controller (RTC) or DRACULA would be more appropriate (Liu, 2005). Likewise, some form of distance decay analysis should be conducted to determine how far out traffic normalizes from a facility receiving increased freight throughput.

8.5.2 NIT Port Performance Analysis

This research focused on the network effect of the Jones Act restriction on freight transportation, it did not focus on how individual facilities, such as ports, handle throughput increases. An initial attempt was made to study how increasing freight throughput at ports would impact port performance. However, two problems arose; first, there as a lack of data or performance measures to analyze how increased container throughput would affect port operations and performance.

If a possible simulation program could be developed to scale to large port facilities, possible future research would be timely with recent work by the Bureau of Transportation Statistics (BTS) to develop port performance measures to study port capacity and throughput (BTS, 2016). In accordance with the Fixing America's Surface Transportation (FAST) Act, BTS established the Port Performance Freight Statistics Program. The overall goal of the Port Performance Freight Statistics Program is to "develop 'consistent measures of performance' for the Nation's largest ports, and to report annually to Congress on port capacity and throughput" (BTS, p.iii, 2016). In its 2016 Annual report to Congress, BTS outlined various metrics for port performance including channel depth, berth length, number of container cranes, as well as container throughput, vessel calls, and total tonnage moving through the facilities (BTS, 2016).

8.6 Concluding Thoughts: "Disasters have Consequences"

It is fitting to end the dissertation the same way it started, "disasters have consequences." Disasters force planners and policymakers to make choices on how to utilize scarce resources to assist in bringing about recovery. It is important to recognize that those choices include how laws and policies affect recovery, particularly as it relates to ensuring critical infrastructures continue to operate for the communities and stakeholders that rely on them. With ever-increasing uncertainty and complexity between critical infrastructure systems, increasing societal needs and reliance on those infrastructures, and the role of law and governance in the pursuit of ensuring continuous functionality, we must strive to cross bridges, to understand and study the linkages between law, policy, and infrastructure.

Disasters and their aftermath provide a window of opportunity to learn. In understanding how law and policy can affect transportation in the aftermath of disruption, the lessons learnt are on a two-way street. Where policy makers can see the impact of law on the built environment and engineers can learn how the law may add or relieve stress on the infrastructures they designed, to ensure that society, as a whole is ready for the uncertainty that lies ahead.

8.7 References

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Appendix A: Distance Table and Truck Count Tables

Appendix A1: FAF Zones

The following tables were generated as part of the highway analysis and converting the FAF data into truck counts before being added to the batch routing files for processing in TRAGIS. The FAF dataset is based on zone-to-zone freight flows. For simplification, the following table is a key for which FAF zone was used in the distance calculation and the truck conversion tables.

Table A.1: FAF Zones used in Highway Analysis

ID	FAF Zone Number	FAF Zone		ID	FAF Zone Number	FAF Zone
A	241	Baltimore		**O**	109	Remainder of Maryland
B	371	Charlotte		**P***	249	Remainder of New Jersey*
C	111	DC Part-Washington		**Q**	379	Remainder of North Carolina
D	101	DE Part-Philadelphia		**R**	429	Remainder of Pennsylvania
E	372	Greensboro		**S**	459	Remainder of South Carolina
F	242	MD Part-Washington		**T**	519	Remainder of Virginia
G	341	NJ Part-NYNJPACT		**U**	511	Richmond
H	342	NJ Part-Philadelphia		**V**	513	VA Part-Washington
I	512	Norfolk		**W**	540	West Virginia
J	363	NY Part-NYNJPACT		**1**	121	Jacksonville
K	421	PA Part-Philadelphia		**2**	471	Memphis
L	422	Pittsburgh		**3**	292	St. Louis
M	373	Raleigh Durham		**4**	171	Chicago
N	241	Remainder of Delaware		**5**	251	Boston

Credit: M. Fialkoff (2017)

* Within the FAF dataset, no information was available for freight flows emanating from the FAF zone designated as “Remainder of New Jersey.” The subsequent tables omit a “P” row and “P” column since no data existed.

Appendix A2: Distance Matrix

This table is a distance matrix between the origins and destinations used for the highway analysis. The letters and numbers along the top and side correspond to the ID values in Appendix A1.

Table A.2: Distance Table

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q	R	S	T	U	V	W	1	2	3	4	5
A	0																										
B	446	0																									
C	38	399	0																								
D	75	512	108	0																							
E	355	92	309	425	0																						
F	34	413	6	106	324	0																					
G	183	620	216	119	531	213	0																				
H	106	543	140	33	454	136	88	0																			
I	240	325	195	247	235	209	354	277	0																		
J	176	613	210	113	524	206	15	81	348	0																	
K	106	543	139	33	453	135	88	5	277	82	0																
L	247	447	245	299	427	236	360	309	430	374	305	0															
M	323	166	278	393	77	292	500	423	185	494	422	502	0														
N	105	505	104	86	416	107	193	117	161	188	116	340	344	0													
O	74	405	72	147	320	63	232	177	257	237	176	176	341	168	0												
Q	361	134	316	431	94	330	538	461	223	532	460	518	64	383	379	0											
R	78	514	119	66	433	112	155	84	318	149	80	238	163	134	112	440	0										
S	524	93	478	594	183	493	701	624	386	695	623	539	226	546	498	166	602	0									
T	154	272	116	226	180	123	333	256	164	327	255	318	241	223	174	279	232	363	0								
U	154	291	109	224	202	123	331	254	93	325	253	344	170	216	171	208	233	371	72	0							
V	57	391	20	129	302	26	236	159	187	230	158	247	270	129	74	308	135	471	100	101	0						
W	365	264	362	437	244	354	521	467	409	526	466	228	318	459	294	334	395	355	248	316	353	0					
1	751	383	706	821	456	720	928	851	613	922	850	829	454	773	769	393	830	294	669	599	698	646	0				
2	914	619	877	986	675	883	1,086	1,016	917	1,091	1,015	772	749	987	858	759	967	598	757	825	861	599	729	0			
3	821	713	818	880	749	810	941	890	914	954	886	602	823	915	750	839	820	747	753	821	820	506	901	283	0		
4	701	755	698	753	734	690	779	763	884	799	759	460	809	795	630	825	692	800	739	797	700	491	1,062	532	297	0	
5	404	841	438	341	752	434	224	309	576	238	310	572	721	415	463	759	376	921	555	551	457	752	1,149	1,317	1,193	984	0

Credit: M. Fialkoff (2017)

Appendix A3: Annual Truck Counts by Zone

The following tables are the calculated yearly truck counts moving between each zone used for this study. The letters and numbers along the top and side correspond to the ID values in Appendix A1.

Table A.3: Annual Truck Counts by Zone (A through M)

	A	B	C	D	E	F	G	H	I	J	K	L	M
A	2,295,058	9,518	39,507	31,707	9,144	309,898	100,230	43,023	43,924	169,934	74,844	17,740	6,121
B	2,865	1,560,806	203	1,815	151,869	2,811	6,144	3,402	13,206	3,649	4,883	3,373	54,060
C	10,246	92	118,248	4,044	79	35,720	91	44	30,514	396	1,655	1,005	55
D	13,659	14,918	2,336	1,142,890	421	5,307	111,881	31,470	995	19,611	84,007	11,212	386
E	8,919	136,799	1,424	8,761	1,619,800	14,427	8,772	9,917	20,388	9,331	11,258	4,159	125,516
F	135,742	2,164	58,165	10,162	516	1,038,859	3,042	8,841	26,312	2,295	22,029	4,627	2,800
G	80,533	23,587	5,098	35,753	9,772	22,117	7,501,016	308,890	26,579	3,017,344	396,994	70,296	11,947
H	43,772	4,152	1,582	84,792	1,303	20,813	414,453	1,614,008	5,204	18,579	416,510	19,917	3,378
I	40,710	13,281	2,621	3,346	31,467	8,099	16,221	5,160	1,426,653	30,157	5,812	7,674	45,758
J	42,373	5,100	1,687	16,603	2,896	6,451	1,238,634	67,317	64,375	6,447,462	147,223	27,256	2,580
K	80,863	10,926	2,890	111,905	4,546	22,500	456,455	464,242	18,368	353,713	2,753,301	64,255	3,661
L	455,468	10,235	1,477	7,586	2,288	7,838	61,475	30,415	391,328	20,381	30,032	2,471,090	818
M	8,385	41,506	339	922	91,354	8,473	3,452	10,951	22,934	4,005	2,822	2,898	1,445,839
N	14,743	159	6,735	41,503	100	1,050	8,941	16,012	1,091	7,739	7,563	5,059	2
O	124,197	1,649	2,930	51,613	1,506	72,628	36,290	14,414	94,314	13,902	46,340	10,670	3,060
Q	26,885	148,613	1,809	4,004	146,483	7,034	15,541	7,897	103,740	34,998	29,991	16,286	274,058
R	251,601	20,655	5,352	113,324	17,458	128,657	320,260	145,224	42,138	25,620	580,910	527,287	22,859
S	8,430	244,758	139	4,103	51,210	5,876	10,117	7,235	15,303	4,468	7,563	5,679	35,127
T	67,430	60,873	4,363	13,599	74,056	52,808	34,043	23,339	78,614	26,222	25,784	15,946	500,016
U	31,432	7,815	6,529	2,089	23,831	18,985	10,607	3,370	195,908	12,963	14,199	5,701	21,241
V	16,555	2,442	46,282	4,251	43,348	173,952	6,188	4,255	13,728	5,312	5,829	5,195	3,535
W	23,819	4,796	10,305	4,026	8,931	18,081	14,172	7,740	15,256	3,192	31,412	73,918	1,945
1	378	12,440	31	236	8,733	171	4,564	727	1,825	5,128	1,556	1,448	9,626
2	149	1,284	24	102	7,498	596	1,951	279	710	797	799	214	359
3	3,347	2,915	33	207	3,856	187	7,687	1,849	4,397	3,309	2,698	3,122	776
4	21,497	10,031	1,919	1,358	12,701	4,255	60,039	6,631	38,239	22,980	31,307	35,202	4,697
5	6,196	287	387	5,155	5,447	1,750	63,131	13,149	13,622	66,898	16,034	3,536	1,635

Credit: M. Fialkoff (2017)

Annual Truck Counts by Zone Continued

Table A.4: Annual Truck Counts by Zone (N through 5)

	N	O	Q	R	S	T	U	V	W	1	2	3	4	5
A	17,584	118,617	9,990	234,916	6,965	34,683	48,587	182,245	14,840	3,637	766	2,179	15,765	24,164
B	732	738	241,915	7,548	497,659	49,259	8,172	2,307	8,377	5,772	2,407	1,508	8,489	3,463
C	30	2,325	91	9,534	37	12,091	33,094	23,447	50	34	7	17	109	224
D	61,499	13,961	5,639	47,093	1,127	2,594	1,885	12,325	1,141	122	145	687	2,296	4,185
E	1,138	6,810	173,886	32,936	85,989	95,289	15,481	20,010	11,453	6,785	4,052	1,746	7,036	9,776
F	8,469	34,598	3,296	52,298	1,861	36,519	31,169	141,834	3,334	64	176	112	879	913
G	4,340	20,961	18,789	273,781	13,635	12,174	18,834	34,884	3,879	4,177	4,450	10,134	131,939	181,926
H	174,138	15,027	4,318	114,047	1,886	15,077	6,911	13,115	2,968	6,365	658	2,865	15,907	38,861
I	859	12,726	69,958	25,905	12,509	76,784	74,065	22,804	5,387	5,019	1,379	2,362	14,651	6,136
J	692	4,512	27,495	94,445	7,327	15,656	27,301	35,069	1,019	8,693	2,461	1,388	10,789	36,344
K	23,775	41,487	8,447	627,923	2,529	19,492	9,926	13,234	5,421	2,005	601	2,670	35,669	37,776
L	67	16,553	4,647	246,769	2,517	10,051	4,514	6,297	82,895	507	1,142	4,355	24,165	11,076
M	480	1,966	520,570	8,389	43,678	36,618	28,027	5,993	12,266	4,657	320	526	8,147	2,100
N	342,511	95,393	1,609	4,149	198	4,432	506	1,177	55	285	8	8	753	2,308
O	85,673	897,879	4,716	11,467	463	126,134	21,550	20,588	61,181	432	19	259	3,688	5,959
Q	1,764	6,608	3,953,721	55,495	172,496	135,375	49,192	11,606	18,546	12,562	2,054	5,090	31,989	7,886
R	33,102	128,603	33,997	7,197,021	120,723	90,462	34,631	54,264	89,858	6,427	2,022	3,804	54,888	109,832
S	2,180	10,722	221,828	26,640	2,425,215	36,137	9,478	12,638	10,324	14,277	2,543	4,300	20,341	5,630
T	1,146	37,890	239,730	78,656	17,115	3,138,759	195,305	118,869	123,632	5,562	4,162	3,689	17,738	18,105
U	8,318	13,271	43,026	29,652	8,467	273,814	1,445,573	55,383	39,251	495	656	438	6,127	3,243
V	1,307	16,555	6,512	12,635	1,007	51,390	31,770	1,534,305	6,941	252	773	85	937	1,358
W	57	19,586	11,536	87,934	8,555	55,289	9,695	26,044	2,008,980	648	7,434	1,953	16,948	3,430
1	13	231	11,209	1,544	16,621	4,242	957	896	1,498	1,658,357	5,152	1,002	4,512	2,004
2	15	253	774	6,489	1,673	1,298	463	300	2,202	2,677	974,991	2,883	12,421	1,025
3	0	31	1,093	13,396	907	2,044	319	175	1,985	1,407	10,885	1,590,594	70,646	1,536
4	12	8,092	23,853	54,187	20,106	16,870	5,438	6,851	13,472	21,925	9,244	56,057	9,966,626	9,971
5	34	2,179	1,864	18,402	1,778	1,850	2,857	2,012	654	1,182	1,828	1,000	9,031	5,248,954

Credit: M. Fialkoff (2017)

Appendix A4: Daily Truck Counts by Zone

The following tables are the calculated daily truck counts moving between each zone used for this study. The letters and numbers along the top and side correspond to the ID values in Appendix A1.

Table A.5: Annual Truck Counts by Zone (A through M)

	A	B	C	D	E	F	G	H	I	J	K	L	M
A	6,288	26	108	87	25	849	275	118	120	466	205	49	17
B	8	4,276	1	5	416	8	17	9	36	10	13	9	148
C	28	0	324	11	0	98	0	0	84	1	5	3	0
D	37	41	6	3,131	1	15	307	86	3	54	230	31	1
E	24	375	4	24	4,438	40	24	27	56	26	31	11	344
F	372	6	159	28	1	2,846	8	24	72	6	60	13	8
G	221	65	14	98	27	61	20,551	846	73	8,267	1,088	193	33
H	120	11	4	232	4	57	1,135	4,422	14	51	1,141	55	9
I	112	36	7	9	86	22	44	14	3,909	83	16	21	125
J	116	14	5	45	8	18	3,394	184	176	17,664	403	75	7
K	222	30	8	307	12	62	1,251	1,272	50	969	7,543	176	10
L	1,248	28	4	21	6	21	168	83	1,072	56	82	6,770	2
M	23	114	1	3	250	23	9	30	63	11	8	8	3,961
N	40	0	18	114	0	3	24	44	3	21	21	14	0
O	340	5	8	141	4	199	99	39	258	38	127	29	8
Q	74	407	5	11	401	19	43	22	284	96	82	45	751
R	689	57	15	310	48	352	877	398	115	70	1,592	1,445	63
S	23	671	0	11	140	16	28	20	42	12	21	16	96
T	185	167	12	37	203	145	93	64	215	72	71	44	1,370
U	86	21	18	6	65	52	29	9	537	36	39	16	58
V	45	7	127	12	119	477	17	12	38	15	16	14	10
W	65	13	28	11	24	50	39	21	42	9	86	203	5
1	1	34	0	1	24	0	13	2	5	14	4	4	26
2	0	4	0	0	21	2	5	1	2	2	2	1	1
3	9	8	0	1	11	1	21	5	12	9	7	9	2
4	59	27	5	4	35	12	164	18	105	63	86	96	13
5	17	1	1	14	15	5	173	36	37	183	44	10	4

Credit: M. Fialkoff (2017)

Daily Truck Counts by Zone Continued

Table A.6: Daily Truck Counts by Zone (N through 5)

	N	O	Q	R	S	T	U	V	W	1	2	3	4	5
A	48	325	27	644	19	95	133	499	41	10	2	6	43	66
B	2	2	663	21	1,363	135	22	6	23	16	7	4	23	9
C	0	6	0	26	0	33	91	64	0	0	0	0	0	1
D	168	38	15	129	3	7	5	34	3	0	0	2	6	11
E	3	19	476	90	236	261	42	55	31	19	11	5	19	27
F	23	95	9	143	5	100	85	389	9	0	0	0	2	3
G	12	57	51	750	37	33	52	96	11	11	12	28	361	498
H	477	41	12	312	5	41	19	36	8	17	2	8	44	106
I	2	35	192	71	34	210	203	62	15	14	4	6	40	17
J	2	12	75	259	20	43	75	96	3	24	7	4	30	100
K	65	114	23	1,720	7	53	27	36	15	5	2	7	98	103
L	0	45	13	676	7	28	12	17	227	1	3	12	66	30
M	1	5	1,426	23	120	100	77	16	34	13	1	1	22	6
N	938	261	4	11	1	12	1	3	0	1	0	0	2	6
O	235	2,460	13	31	1	346	59	56	168	1	0	1	10	16
Q	5	18	10,832	152	473	371	135	32	51	34	6	14	88	22
R	91	352	93	19,718	331	248	95	149	246	18	6	10	150	301
S	6	29	608	73	6,644	99	26	35	28	39	7	12	56	15
T	3	104	657	215	47	8,599	535	326	339	15	11	10	49	50
U	23	36	118	81	23	750	3,960	152	108	1	2	1	17	9
V	4	45	18	35	3	141	87	4,204	19	1	2	0	3	4
W	0	54	32	241	23	151	27	71	5,504	2	20	5	46	9
1	0	1	31	4	46	12	3	2	4	4,543	14	3	12	5
2	0	1	2	18	5	4	1	1	6	7	2,671	8	34	3
3	0	0	3	37	2	6	1	0	5	4	30	4,358	194	4
4	0	22	65	148	55	46	15	19	37	60	25	154	27,306	27
5	0	6	5	50	5	5	8	6	2	3	5	3	25	14,381

Credit: M. Fialkoff (2017)

Appendix B: Supplemental Maps and Materials: 2011-2013 CCWS

The following are supplemental maps representing rail flow from the study area for the Confidential Carload Waybill Sample for years 2011, 2012, and 2013. In accordance with 49 CFR § 1244.9 and instructions in the acceptance letter (WB16-12, page 2, point 2), the results from the railroad section were submitted to Mr. Alexander Dusenberry with the Surface Transportation Board for review in accordance with the above-mentioned regulation. The regulations restrict the level of detail and results need to be aggregated to ensure they do not reflect the movement of goods by a particular railroad company.

Figures B1 through B5 represent the daily train traffic moving across the United States from the data used from the Confidential Carload Waybill Sample for 2011 through 2013. Figures B6 and B7 represent rail traffic follows in the Mid-Atlantic region for 2011 and 2013. Figure B8 illustrate the distribution of goods leaving the Norfolk International Terminal and the geographic distribution of freight based on Bureau of Economic Analysis (BEA) regions.

Appendix B1: 2011 Daily Train Traffic Flow

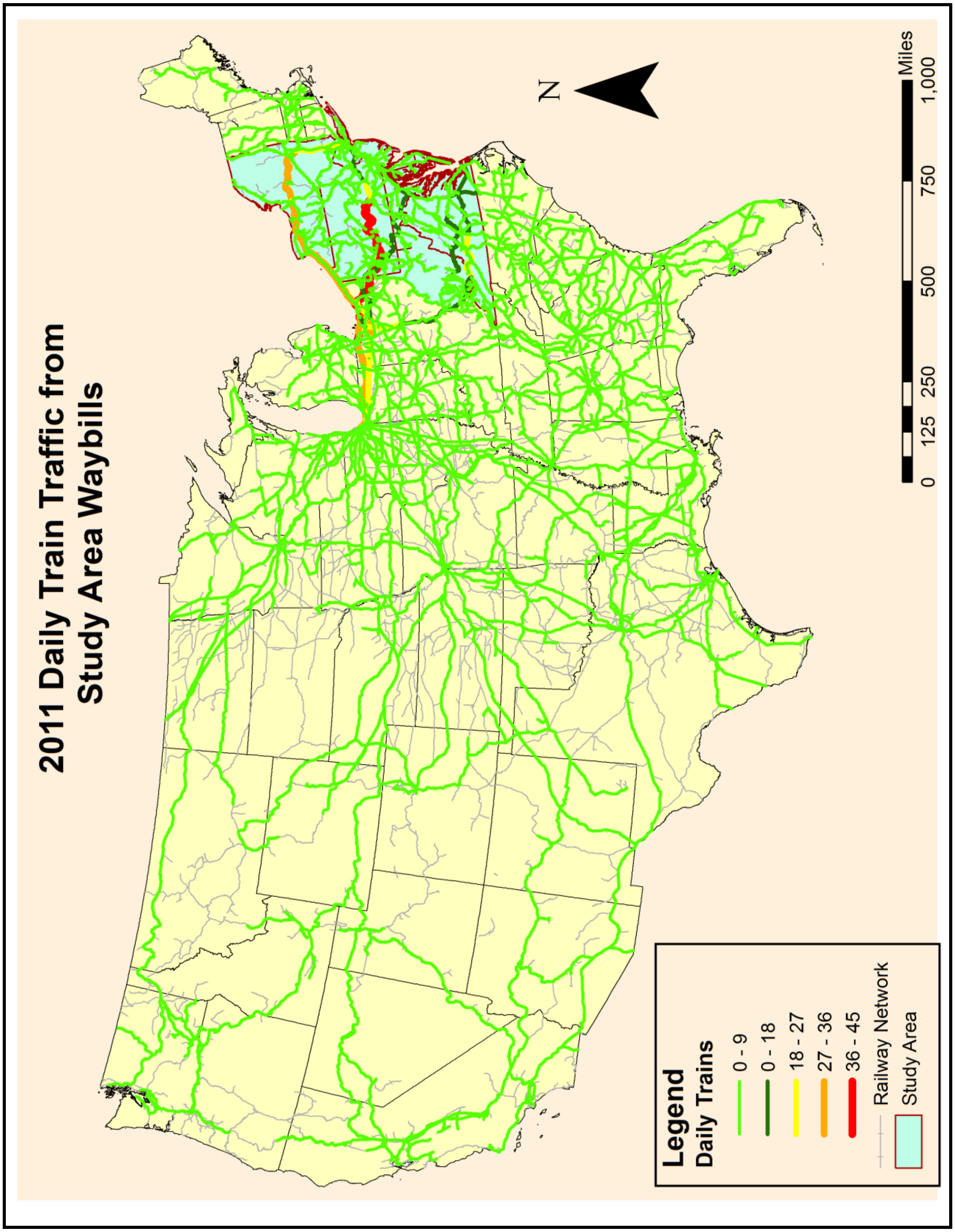

Figure B.1: 2011 Daily Train Traffic Flow
Credit: M. Fialkoff (2017)

Appendix B2: 2012 Normal Daily Train Traffic Flow

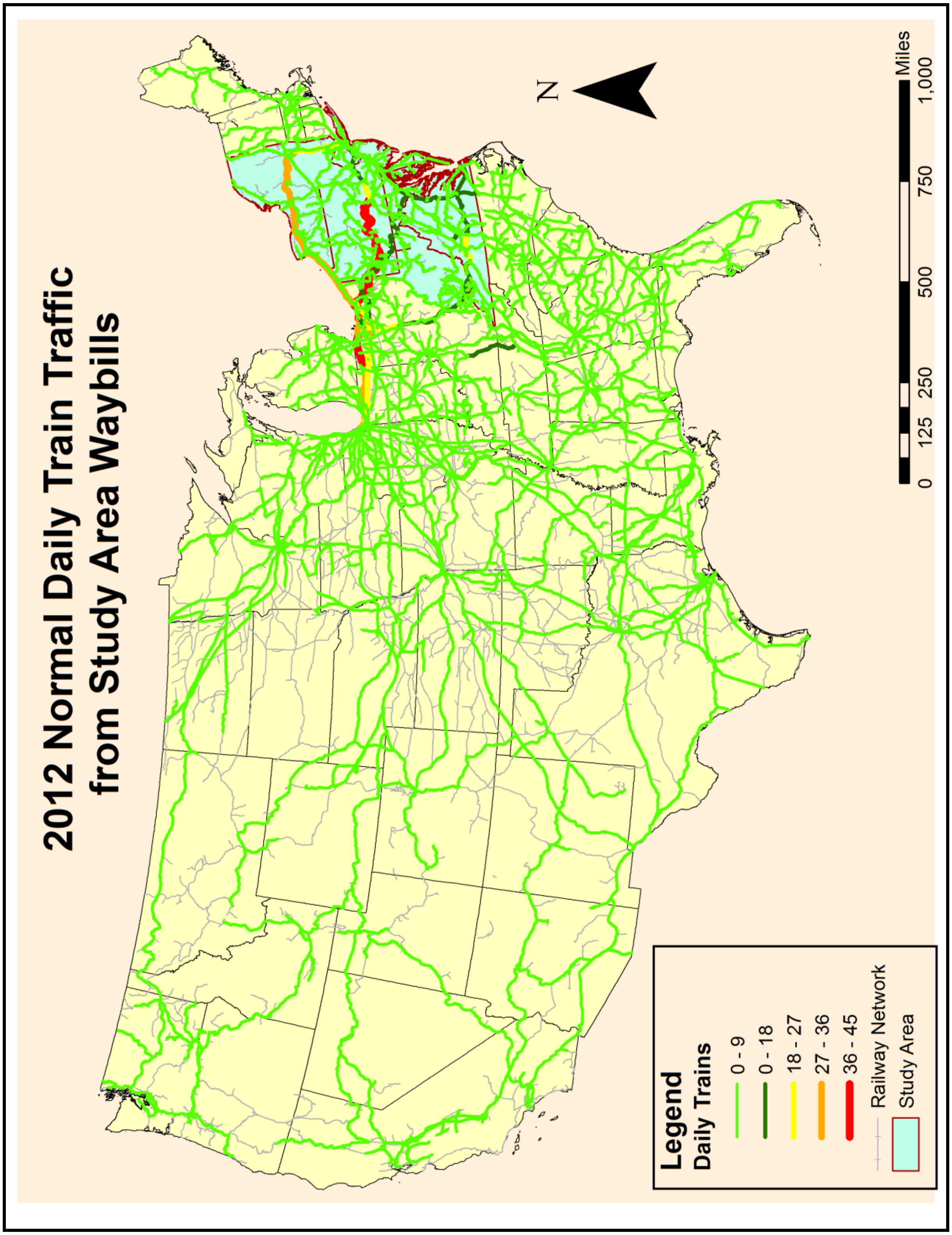

Figure B.2: 2012 Normal Daily Train Traffic Flow
Credit: M. Fialkoff (2017)

Appendix B3: 2012 Daily Train Traffic Flow-Hurricane Sandy - Jones Act in Place

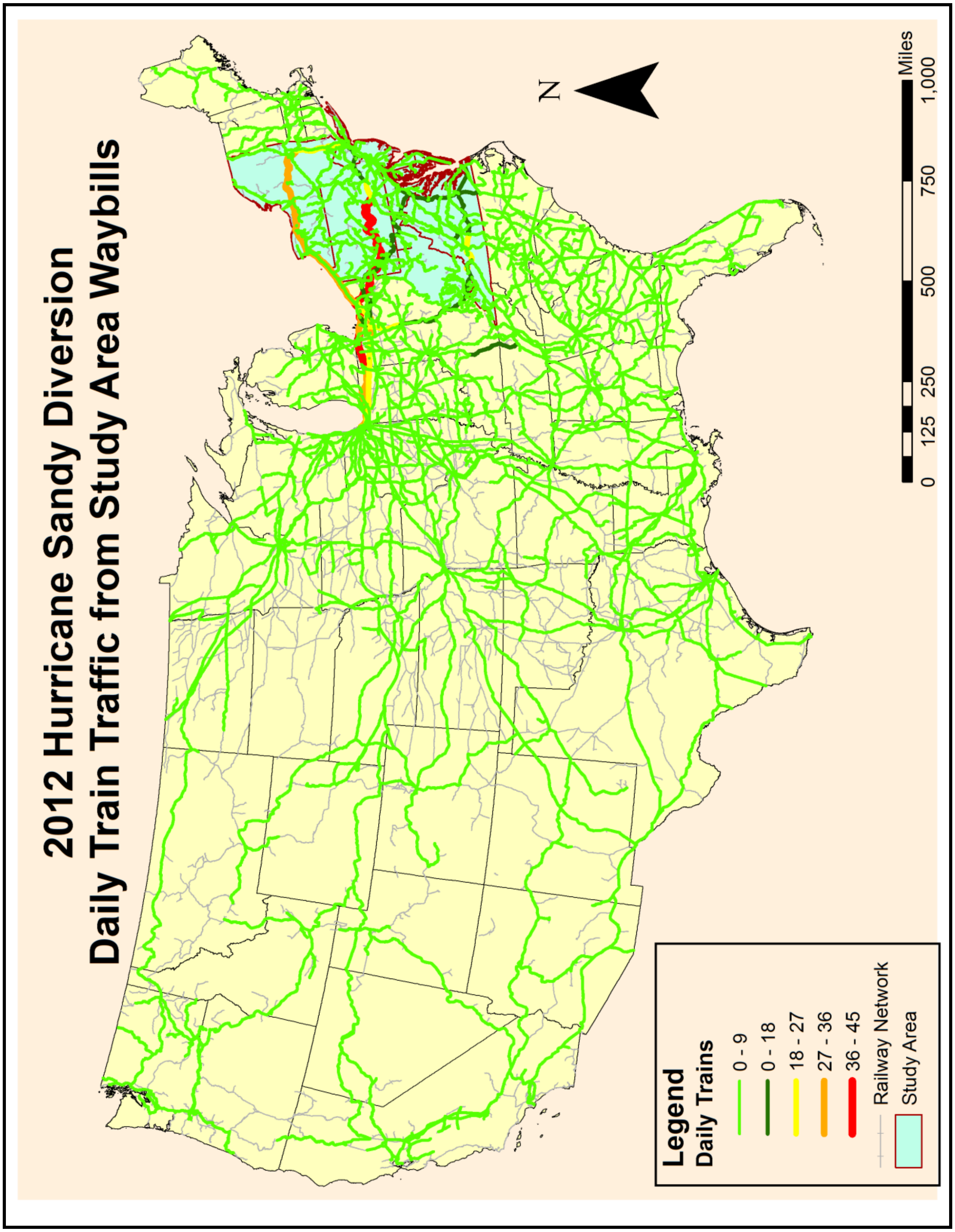

Figure B.3: 2012 Daily Train Traffic Flow: Hurricane Sandy - Jones Act in Place
Credit: M. Fialkoff (2017)

Appendix B4: 2012 Daily Train Traffic Flow-Hurricane Sandy - Jones Act Relaxed

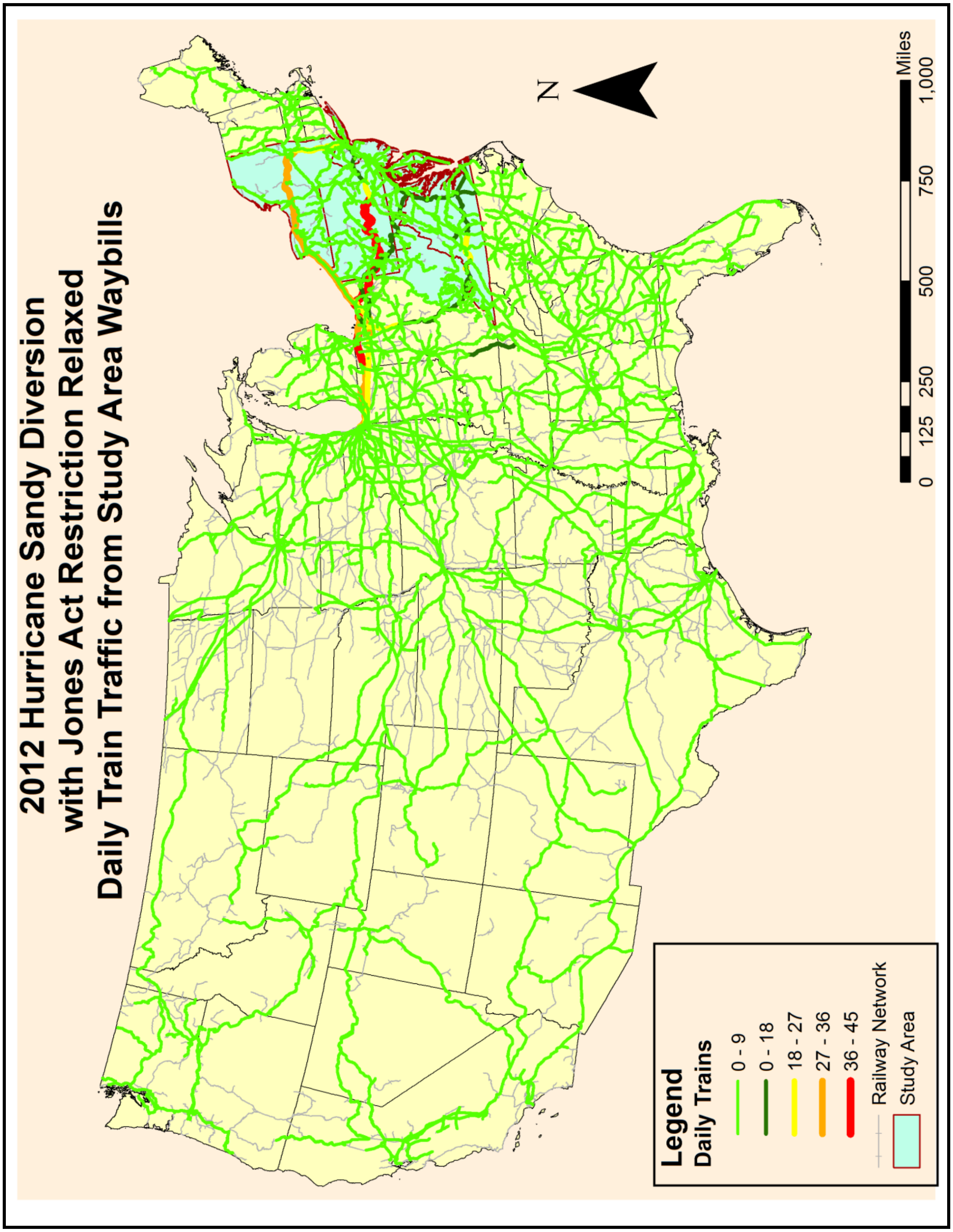

Figure B.4: 2012 Daily Train Traffic Flow: Hurricane Sandy - Jones Act Relaxed
Credit: M. Fialkoff (2017)

Appendix B5: 2013 Daily Train Traffic Flow

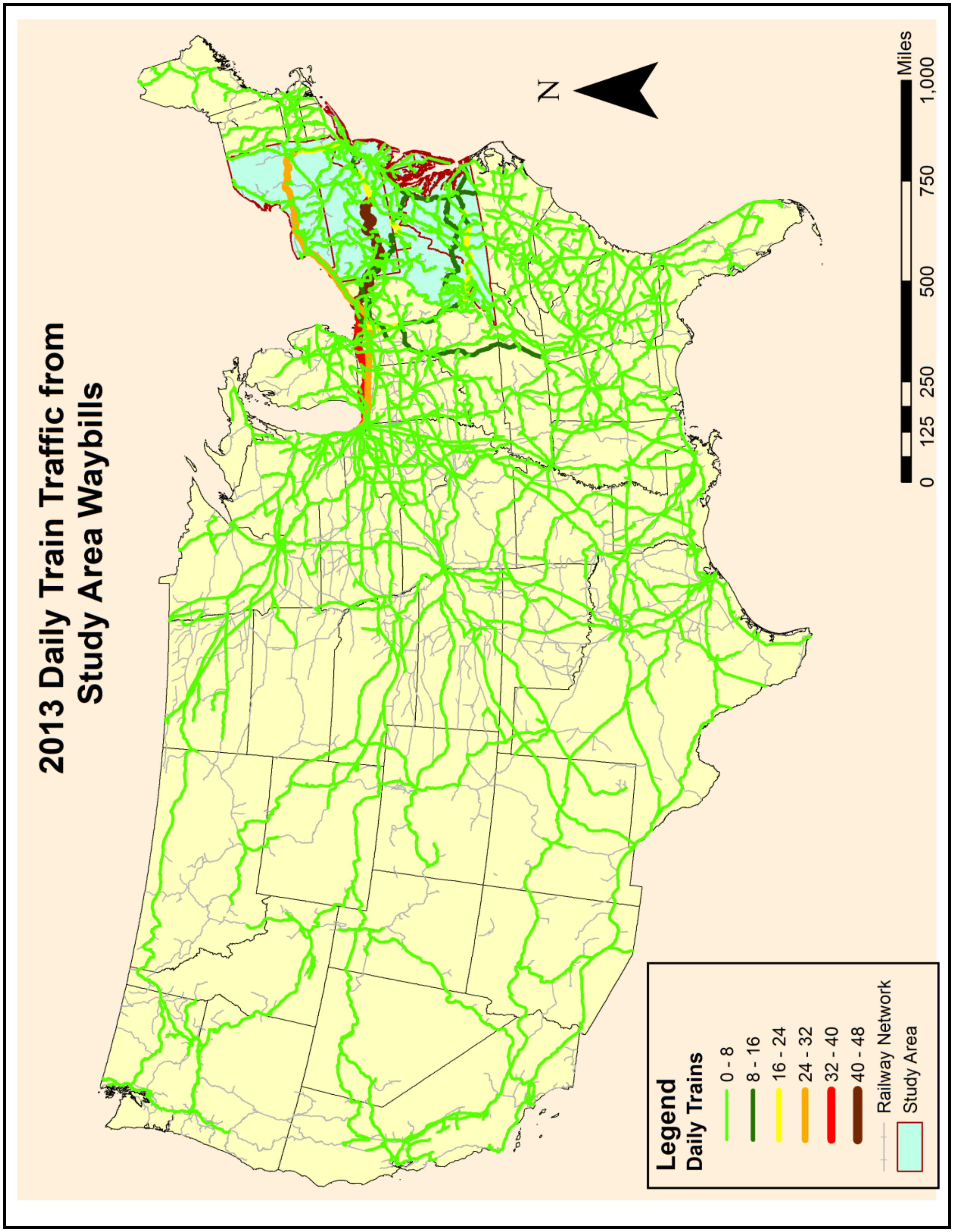

Figure B.5: 2013 Daily Train Traffic
Credit: M. Fialkoff (2017)

Appendix B6: 2011 Rail Traffic Volume for Mid-Atlantic States

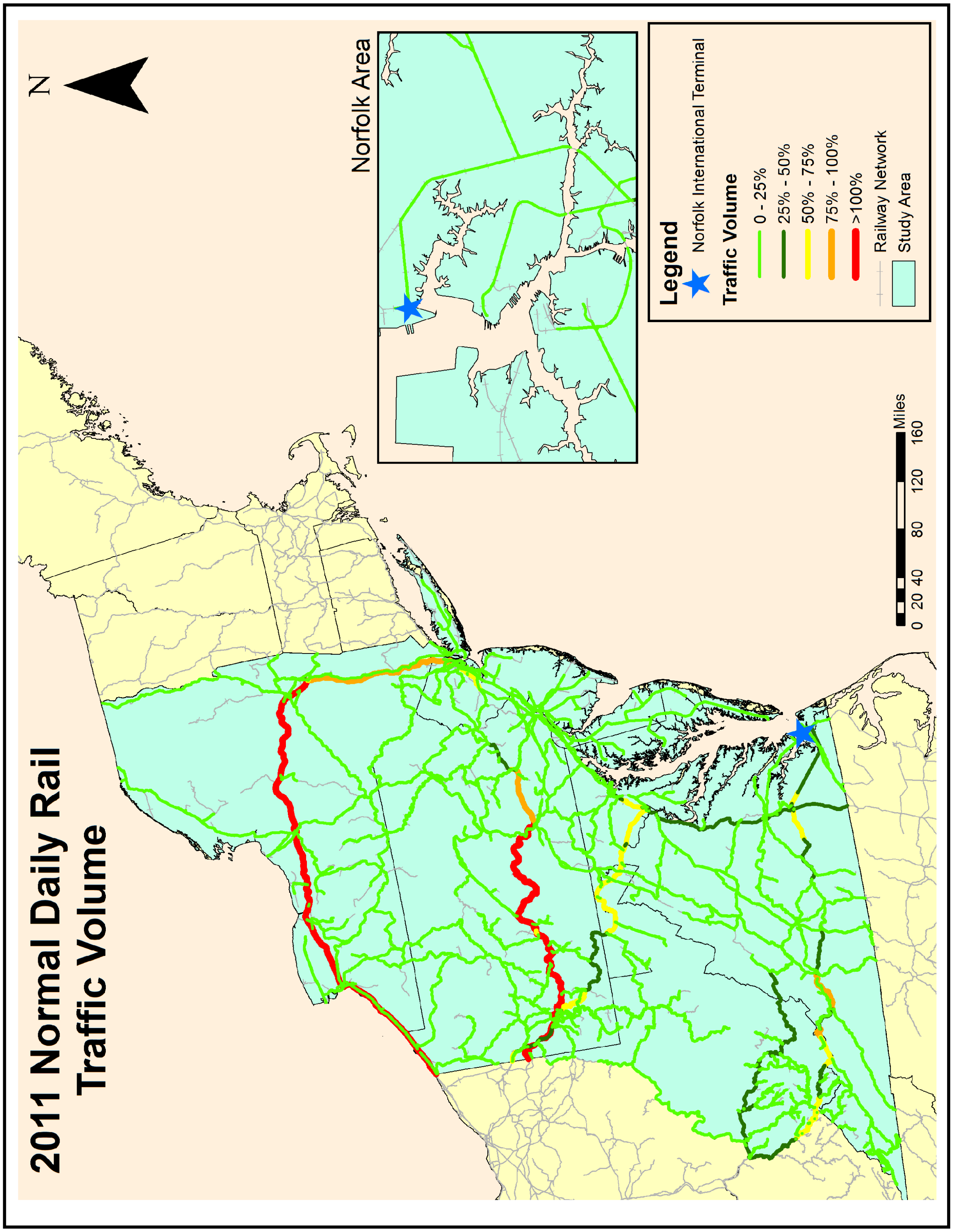

Figure B.6: 2011 Daily Rail Traffic Volume
Credit: M. Fialkoff (2017)

Appendix B7: 2013 Rail Traffic Volume for Mid-Atlantic States

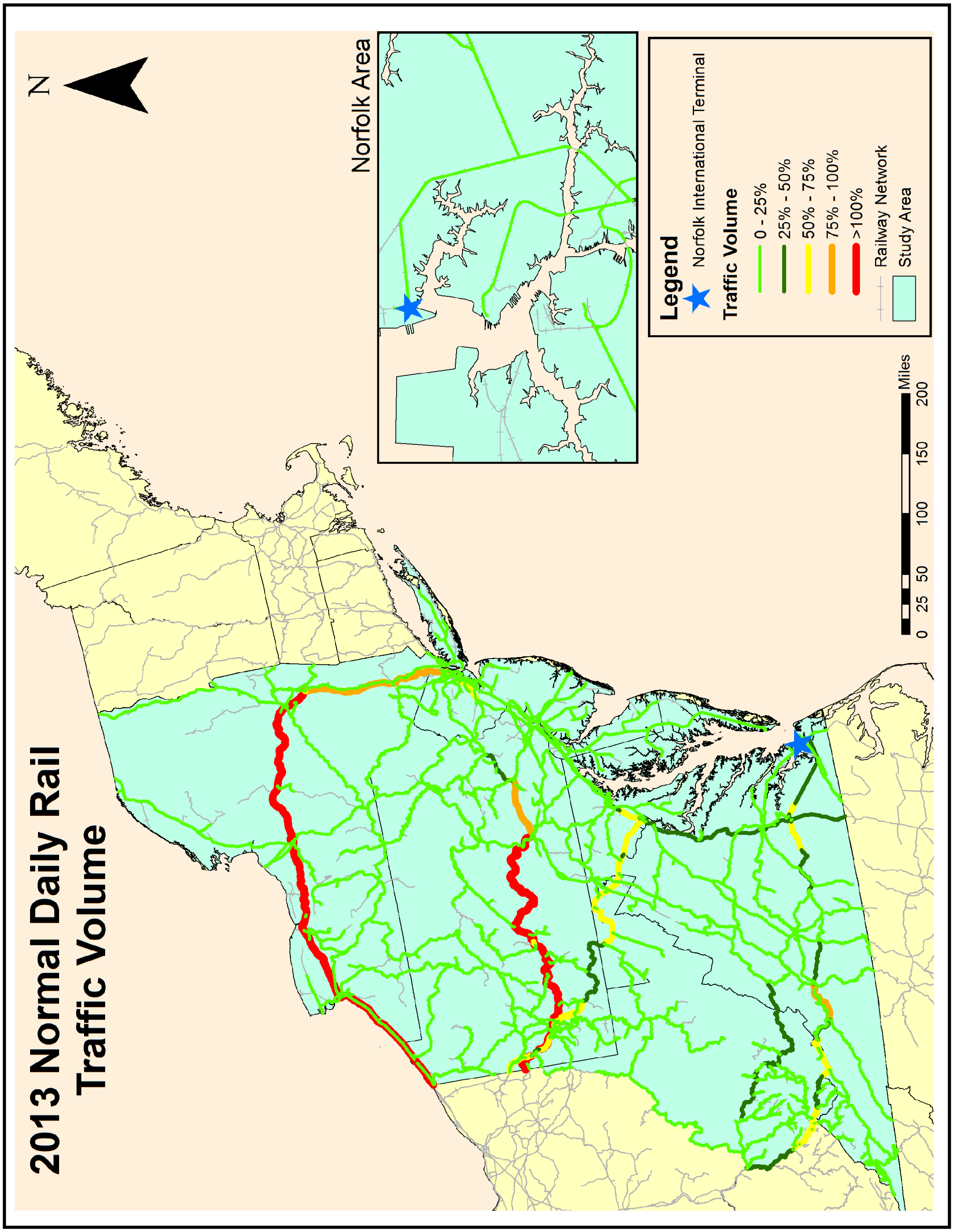

Figure B.7: 2013 Daily Rail Traffic Volume
Credit: M. Fialkoff (2017)

Appendix B8: Container Flow Traffic Leaving Norfolk International Terminal

Table B.1: Percentage of Container Flow leaving NIT for Selected BEA Regions

BEA Region	2011	2012 Scenario 1	2012 Scenario 2	2012 Scenario 3	2013
Great Lakes	63.89 %	65.1 %	65.12 %	65.13 %	68.17 %
Plains	9.97 %	9.61 %	9.60 %	9.60 %	9.40 %
Southeast	26.14 %	25.29 %	25.28 %	25.28 %	22.43 %
	100 %	100 %	100 %	100.01[10] %	100 %

Credit: M. Fialkoff (2017)

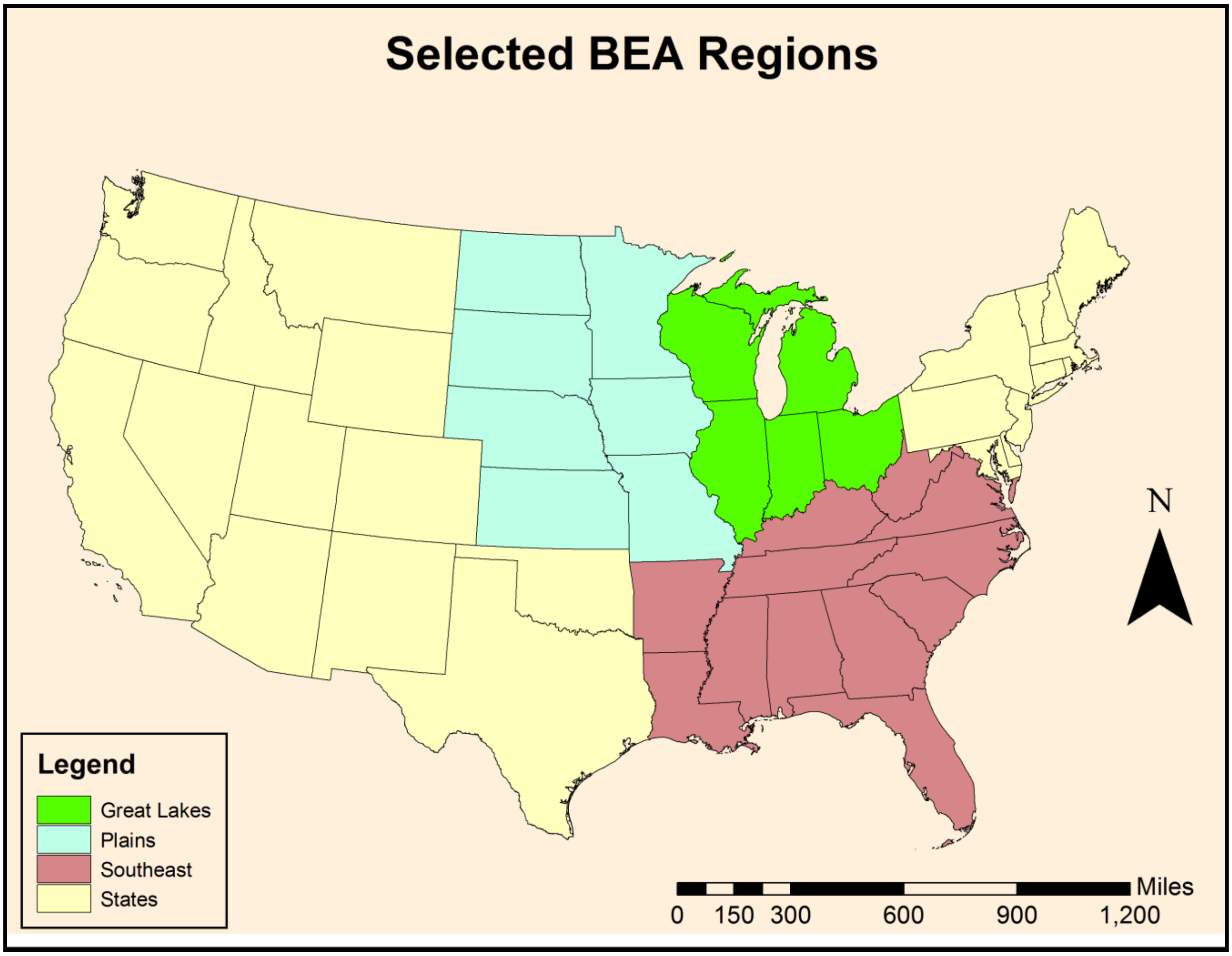

Figure B.8: Bureau of Economic Analysis (BEA) Regions
Credit: M. Fialkoff (2017)

[10] This is due to rounding.

Appendix C: STB Documentation Approving use of 2011-2013 Confidential Carload Waybill Sample

This section contains copies of the request made by Dr. Steven K. Peterson (ORNL) on behalf of Marc Fialkoff for access to the 2011, 2012, and 2013 Confidential Carload Waybill Sample. The request was made on March 16, 2016 and approved on March 17, 2016. Original Copies of the request and compliance documents are on file with the author. In addition, copies of the documents are also on file with the Graduate School at Virginia Tech and Oak Ridge National Laboratory.

In accordance with 49 CFR § 1244.9 and instructions in the acceptance letter (WB16-12, page 2, point 2), the results from the railroad section were submitted to Mr. Alexander Dusenberry with the Surface Transportation Board for review in accordance with the above-mentioned regulation. As of May 31, 2017, the STB approved all chapters and appendices discussing the CCWS, procedures for manipulating the CCWS, results from the analysis, and maps representing rail flow.

OAK RIDGE
National Laboratory

PO Box 2008
Oak Ridge, TN 37831-6017
(865) 574-4676 | petersonsk@ornl.gov

March 16, 2016

Mr. Alexander Dusenberry
Surface Transportation Board
95 E Street SW
Washington, DC 20423-0001

Dear Mr. Dusenberry:

The Geographic Information Sciences and Technology Group at Oak Ridge National Laboratory (ORNL) performs regular analysis of the US railroad network in support of mission objectives of the US Department of Energy – Office of Environmental Management (DOE-EM), the Federal Railroad Administration – Office of Safety (FRA), and the National Geospatial Intelligence Agency (NGA). In support of these objectives, we have engaged the services of a doctoral student from Virginia Polytechnic Institute and State University, Marc Fialkoff to examine freight system resiliency in the wake of Hurricane Sandy. We believe this study will provide insight into the potential disruptive impacts of storms and other disasters upon the US freight system.

While ORNL has been provided copies of the complete Confidential Waybill Sample in the past on behalf of these constituencies, we are requesting the Mr. Fialkoff be given permission by the Surface Transportation Board (STB) to access the Confidential Waybill Samples for the years 2011 through 2013, which are already in possession by ORNL, in order to assess the rail system impacts of Hurricane Sandy. This information will be used with information supplied to ORNL from the Port of New York/New Jersey, the Virginia Port Authority, the Port of Philadelphia, as well as Norfolk Southern Railroad, CSX Railroad, and Conrail on rail movements through these ports before and after the storm.

This project is being overseen by me and Dr. Femi Omitaomu at ORNL. Mr. Fialkoff will be the primary user of the Confidential Waybill Sample data. However, Dr. Omitaomu or I may be involved in data preparation as necessary to import the information into ORNL systems for subsequent processing and analysis.

Mr. Fialkoff has agreed to sign an STB confidentiality agreement compliant with the statutory requirements found in the applicable section of the Code of Federal Regulations (49 CFR § 1244.9). A signed copy of the agreement is attached.

Sincerely,

Steven Peterson, PhD.
Geographic Information Sciences and Technology Group
Oak Ridge National Laboratory

MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

WAYBILL SAMPLE DATA
SAMPLE DISCLOSURE RESTRICTIONS

This agreement is between Oak Ridge National Laboratory (ORNL) and Mr. Marc Fialkoff of Virginia Polytechnic Institute and State University ("Researcher"). ORNL grants the Researcher access to the Surface Transportation Board's 2011-2013Confidential Waybill Samples for work sponsored by ORNL. These data sets will allow the Researcher to conduct analysis of the impacts of Hurricane Sandy upon US intermodal freight transportation systems.

Under this agreement, the Researcher recognizes the commercial sensitivity of the Waybill Sample data and that improper release of this information could cause competitive harm to the shippers and carriers. The Researcher agrees to comply with the rules applicable to release of the waybill data contained in the Code of Federal Regulations, 49 CFR § 1244.9.

In exchange for the use of the 2011-2013 Confidential Waybill Sample data, the Researcher agrees that he will comply with the following provisions of 49 CFR § 1244.9 Procedures for the release of waybill data.

1. The Researcher shall make no information contained in the STB Waybill Sample available to anyone outside ORNL for any purpose. By signing this agreement, the Researcher recognizes the civil and criminal penalties for unlawful disclosure of information under provisions of 49 CFR § 11904, which include a fine of not more than $50,000 for a person that knowingly discloses certain confidential data made available to such person.

2. The Researcher will ensure that railroads and shippers are afforded the same privilege and protection against disclosure of the waybill data as the STB provides.

3. Prior to the release of any paper, report, thesis, or presentation that contains results from analyses of the Confidential Waybill Sample data, a draft will be submitted to the STB so that it may ensure that shipper and carrier identities have been protected.

The Researcher agrees to comply fully with the provisions of this agreement.

By: Marc R. Fialkoff   Date: March 16, 2016

Marc Fialkoff
Virginia Polytechnic Institute and State University

Surface Transportation Board
Washington, D.C. 20423-0001

Office of Economics

March 17, 2016

Steven Peterson, PhD.
Oak Ridge National Laboratory
PO Box 2008
Oak Ridge, TN 37831-6017

In Response Refer To Waybill Request WB16-12

Dear Mr. Peterson:

The Surface Transportation Board (STB) has approved the Oak Ridge National Laboratory (ORNL) request, on behalf of doctoral student Marc Fialkoff, of March 16, 2016 for permission to access the 2011-2013 STB Carload Waybill Samples already in possession of ORNL. Mr. Fialkoff work is sponsored by ORNL in order to assess the rail system impacts of Hurricane Sandy. "This study will provide insight into the potential disruptive impacts of storms and other disasters upon the U.S. freight system." ***This approval becomes effective when these signed agreement are received by the STB.***

a) ORNL, Steven Peterson PhD.
b) ORNL, Dr. Femi Omitaomu
c) Virginia Tech Doctoral Student, Marc Fialkoff

The expiration date for this agreement is March 31, 2017. Failure to renew an agreement for any year requires you to return or destroy all copies of the data for that year (see item 4 of the agreement).

When using the data the parties must recognize several aspects which limit drawing general conclusions from any potential findings: 1) The waybill data are sample data, and 2) the data are based on terminating shipments from relatively large carriers. Only those railroads with more than 4,500 annual terminating carloads were included in the sample. This limited sampling of very small railroads may have a substantial effect on studies covering small areas served predominately by a non-sampled railroad.

Because contract information is privileged, the revenue field of the waybill sample may not represent the true revenue for contract movements. Railroads are permitted, under certain conditions, to replace the contract revenue with a calculated "masked" figure. The masked revenue figures are typically larger than actual contract revenues, but need not be. Further, there are often end-of-year adjustments provided for in contract rates, typically calling for rebates or discounts once minimum volume commitments are met, that may not always be included in the masked or actual waybill revenue figures. You should not use revenue data from the Carload Waybill Sample in any type of comparison which may lead to wrong or misleading results.

The rules for release of waybill data [Ex Parte No. 385 (Sub-No. 2)] are codified at 49 CFR 1244.9. The waybill data contain confidential shipper and railroad data. As a result, waybill data are commercially sensitive and have the potential for competitive harm to shippers and railroads. Therefore, the following agreement must be signed before any waybill data can be used.

Your signature acknowledges the state's agreement to comply with the following:

1. Your agency/organization shall make the information contained in the Carload Waybill Sample available only to its employees or those contractors working on the particular project or study requiring the waybill data.

2. Your agency/organization will not release any data to the public until the STB has had the opportunity to review the data to ensure its confidentiality.

3. Your agency/organization will refer any requests for waybill data and accompanying documentation to the STB for processing and will so inform the requesting party of such referral to the STB.

4. Your agency/organization must sign an agreement annually with the STB agreeing to these restrictions. **If an annual agreement is not signed, all waybill materials (including all copies) obtained under this agreement will be returned to the STB or your agency must certify that the data has been destroyed**.

After you sign and return this agreement, please contact Mr. Dusenberry (202-245-0319) to make the necessary arrangements to access the data.

Sincerely,

William F. Huneke
Director & Chief Economist

I have read and understand the conditions for release of the waybill data. The ORNL agrees to comply fully with these conditions and the provisions of this confidential agreement. Thirty days before the agreement expires, the ORNL will request an extension of this agreement. If no extension is requested, then we will return or destroy all waybill data and certify that my organization has no copies of the data. I have the authority to sign this agreement for the ORNL.

By: ORNL

[signature]

Signature

Steven Peterson STEVEN PETERSON

Name - Please Print

RESEARCH SCIENTIST – TRANSPORT. GEOGRAPHER

Title

03/18/16

Date

For STB use only:

Signed Agreement Returned: WB16-12 ____________________

Expiration Date: 3/31/16

I have read and understand the conditions for release of the waybill data. Marc Fialkoff of Virginia Tech agrees to comply fully with these conditions and the provisions of this confidential agreement. Thirty days before the agreement expires, the ORNL will request an extension of this agreement. If no extension is requested, then we will return or destroy all waybill data and certify that my university has no copies of the data. I have the authority to sign this agreement for Marc Fialkoff of Virginia Tech.

By:

Virginia Tech Doctoral Student

Marc Fialkoff
Signature

Marc Fialkoff
Name - Please Print Marc Fialkoff

Virginia Tech Doctoral Candidate
Title

March 18, 2016
Date

For STB use only:

Signed Agreement Returned: WB16-12 ______________

Expiration Date: 3/31/17