

Texas Department of Transportation



STATEWIDE
FREIGHT
RESILIENCY
PLAN

Stage 1: Prepare the Freight System







Prepared by



EXPERIENCE | Transportation

Texas Registered Engineering Firm F-3557

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Executive Summary

As the twelfth largest economy in the world and the second largest in the United States, a resilient freight network in Texas is important to the economic health of the State and the nation. Each day millions of dollars of freight move into, out of, and through the state on highways, railroads, water, and air. Ensuring that the movement of these goods, in the face of an event, whether a hurricane, terrorist incident or infrastructure failure, is important not only to Texas but national and international interests.

The Texas Department of Transportation's (TxDOT) recognized that the highway system is a major component of a resilient freight network. As the managing organization responsible for maintaining the State's highways, TxDOT developed this plan to provide a comprehensive framework for identifying key freight infrastructure corridors and strategies to ensure a resilient freight transportation network in the State of Texas.

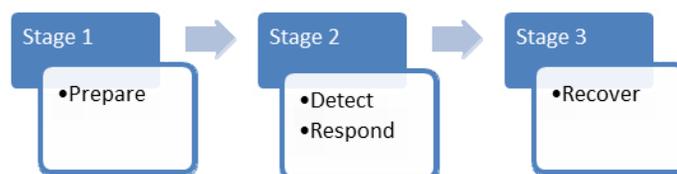
Definition of Freight Transportation System Resilience

Resilience is a term that is used by industry and government in a host of different applications. Only until recently has the resilience term been applied by state departments of transportation (DOTs) to their transportation networks. The currently accepted definition for **freight transportation system resilience** is **"the ability for the system to absorb the consequences of disruptions, to reduce the impacts of disruptions and maintain freight mobility."**

Approach and Process

The approach to developing the Texas Statewide Freight Resiliency (SFR) Plan considers national, state, local, and private plans for infrastructure protection, emergency management, and incident response. Research into these individual plans suggests a common approach to systematically develop a resiliency plan: prepare, detect, respond, and recover. This approach, as presented, appears simple but as the various managing organizations, users, and infrastructure elements are considered the overall plan grows in complexity.

Considering the complexity involved in developing a resiliency plan, the Texas SFR Plan progresses in stages. The stages are phased to accommodate the more familiar prepare, detect, respond, and recover approach. Stage 1 is focused on an assessment of the freight system's preparedness from the perspective of TxDOT as the managing organization. Stage 2 is associated with communication and plan implementation during response to an actual event and its recovery. Stage 3 incorporates a continuous feedback loop that recognizes that change is ever present and the plan must be updated on a regular basis to remain effective.



The purpose of the Texas Statewide Freight Resiliency Plan is to assess the resilience of the strategic freight system in Texas when an event of extended duration limits freight mobility, resulting in prioritized infrastructure enhancements to keep freight moving.

A Resilience Framework for Texas

At the national, state, local, and private levels resilience in its broadest definition – the ability to recover to the original or an improved state – is important for economic health. However, there is no specific framework available that clearly defines how a state DOT can measure or ensure a resilient transportation system.

The Resilience Triangle

In developing a framework specific to Texas, it is first important to clearly set out definitions for related terms: freight transportation system resilience, event, incident, disruption. It is with these definitions that a clear focus is set for the plan. These definitions can best be explained in the context of the “resilience triangle.” The resilience triangle plots the quality or functionality of infrastructure after a loss.

DEFINITIONS

freight transportation system resilience: the ability for the system to absorb the consequences of disruptions, to reduce the impacts of disruptions and maintain freight mobility

event: an overall occurrence or the complete cycle illustrated in the resilience triangle

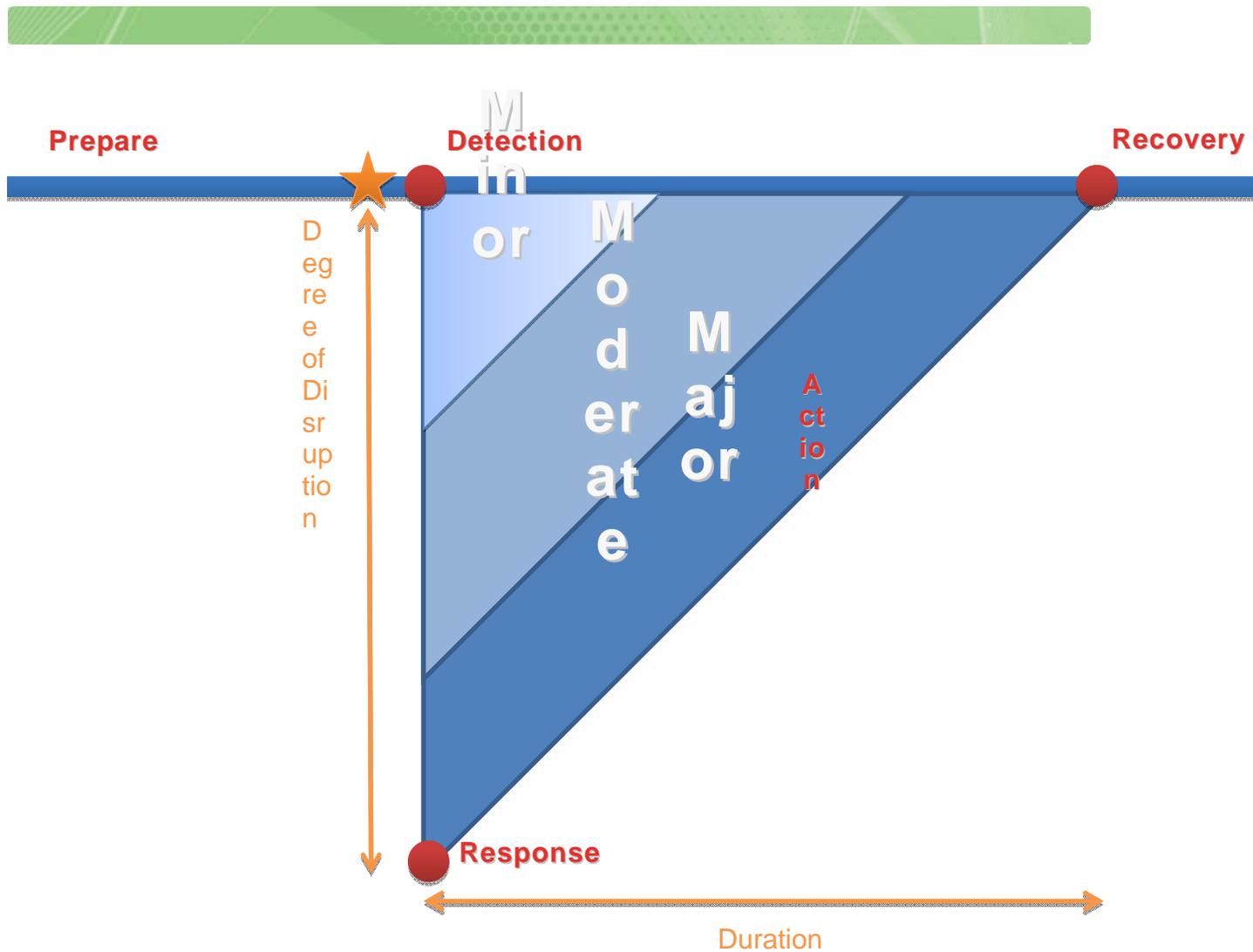
incident: the specific action that occurs at a defined point in time that triggers a change in the transportation system

disruption: what occurs when the incident happens, i.e. a highway is closed due to mudslide or a rail line is out of service due to flooding

degree of disruption: measured as minor, moderate or major based on the duration of time it takes to detect, respond, and recover from the incident

robust: a system that can withstand an incident without significant failure

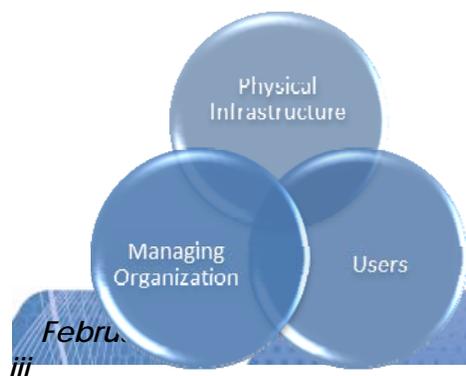
redundant: a system that focuses on the availability of alternate routes or modes



The resilience triangle is sequenced to follow the timeline of the event from normalcy through detection, response, recovery, and back to normalcy. The goal of a resilient freight transportation system is to reside in the “normal” stage of the event cycle. Due to the possibility of disruptive events; however, planning should occur for all stages. Stage 1 of the Texas SFR Plan will focus on the pre-incident stage where the attention is on preparedness.

Dimensions of a Resilient Freight Transportation System

A resilient freight transportation system has three major dimensions: the physical infrastructure, users, and managing organizations.



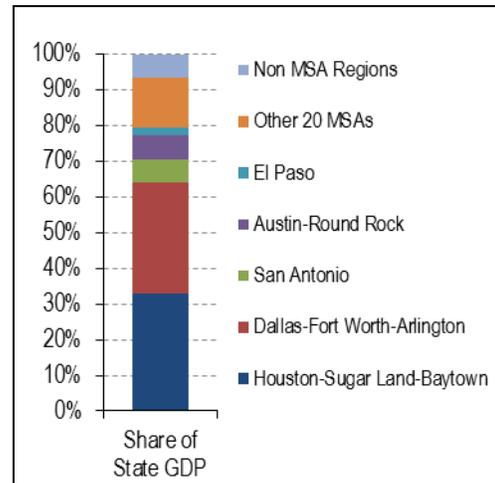
The physical infrastructure is represented by highways, railroads, bridges, ports, and all other assets. The freight transportation system users are represented by the vehicles operating on the network and the managers that direct their travel. The managing organization is responsible for all aspects of the freight transportation

system – operations, maintenance, and communication. A state DOT is the managing organization for the highway transportation network while the railroads are not only the user of the rail network but also the managing organization.

Texas Economy

Texas is an economically diverse and dynamic state with a population of 24.8 million in 2009 (19) and a gross domestic product (GDP) of \$1.2 trillion in 2008 (20). Texas is the second largest state in the US by size of economy and population, accounting for nearly 9 percent of the country's GDP and 8 percent of its population. Long term economic and population growth will place additional demands on the State's freight transportation infrastructure. Population is projected to expand to 33.3 million by 2030 based on interim projections released by the US Census Bureau.

Manufacturing and mining are the two largest contributors to state GDP, accounting for 13.0 percent and 11.3 percent respectively. Other sectors that generate or support freight movements account for a further 21.1 percent of GDP - wholesale trade, retail trade, construction, transportation and warehousing, agriculture, and forestry.



Texas GDP by MSA, 2008

Source: Bureau of Economic Analysis

Freight System Overview

TxDOT, in cooperation with local and regional officials, is responsible for planning, designing, building, operating, and maintaining the state's highway transportation system. The state maintains nearly 79,700 centerline miles comprising of numerous roadway types. Texas has nearly 50,000 bridges which is nearly double the number of bridges of any other state in the nation. Texas has the country's most extensive rail network with 10,743 miles of track and ranks second in total rail carloads (9.4 million in 2008). (24) The 2010 Texas Rail plan indicates that the system has 9,780 public highway - rail crossings.

The Texas economy and its maritime trade are served by eleven port districts, which moved 473 million tons of cargo in 2008 and 19 percent of the nation's port tonnage according to the US Army Corps of Engineers. The dominant cargo flow is inbound international trade followed by outbound international trade. The 1,300-mile Gulf Intracoastal Waterway (GIWW) is a shallow-draft navigation channel that connects ports along the Gulf Coast and provides these ports with access to the country's inland waterway system. In Texas, the GIWW extends for 423 miles from the Sabine River to the Mexican border. The GIWW handled 69 million tons of cargo in 2008.

The Texas airport system is one of the largest in the country with nearly 300 airports, including 27 commercial service airports. In 2009, DFW Airport was the world's third busiest measured by plane movements and was the eighth busiest airport in passenger numbers.

Texas is the primary gateway for US surface trade with Mexico, handling 75 percent of U.S surface trade, 71 percent of imports, and 79 percent of exports in 2009. Trade with a value of \$180 billion flowed through Texas border crossings – 84 percent by truck and 16 percent by rail.

A disruption in Texas' freight system could have significant negative impacts on the national economy, not only Texas. Given the volume of freight moving in the state, any sustained disruption, requiring diversion of one mode to other modes could impact timely and secure delivery of products, product availability, and overall transportation system congestion.

Resilience of the Texas Freight System

The process to assess the resilience of the Texas freight system was developed based on research presented previously and tailored to the specific needs of infrastructure in Texas. Specifically for freight resilience planning, the freight infrastructure and hazards are first identified and then assessed. Once the assessment is complete, any constraints are mitigated and then prioritized. Finally, strategies are developed to guide the on-going, overall freight transportation system resilience efforts.

Corridor and Route Identification

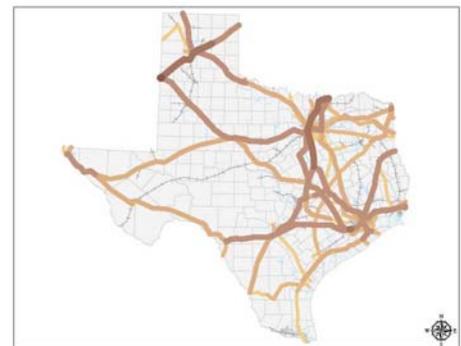
The vast Texas freight system relies on infrastructure – highways, railroads, airports, and waterways – to carry goods from origin to destination and points between. The infrastructure used during normal conditions connects population, employment, and activity centers. Using maps created with Texas-specific data (population and employment density, activity centers, and commodity flows) corridors representing the strategic network for freight movement within the state of Texas were reviewed. Ten specific primary and secondary highway routes were identified within the corridors.

Hazard Identification and Assessment

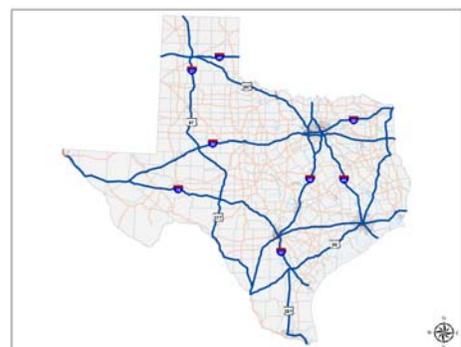
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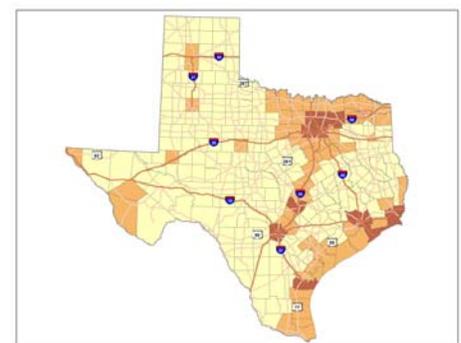
Highway Volumes



Railroad Volumes



Primary Highway Routes



Overall Combined Risk

Past damage to the Texas freight transportation system has occurred from natural and man-made hazards. The purpose of hazard identification and assessment is to locate areas of vulnerability in each corridor to effectively understand how to eliminate or reduce risk associated with a hazard. Each hazard type was assessed based on the frequency of occurrence, warning time, and its potential severity directly related to impacts on the freight transportation system which may be different than impacts to other critical infrastructure, like housing or medical facilities.

The Overall Combined Risk represents the overall vulnerability of the freight transportation system to each of the hazards identified in Texas. The overall combined risk was developed by first combining all data for each hazard by county into one database and then assigning a high, medium, and low overall risk.

The hazard risk assessment uses the results of the overall combined risk to evaluate all corridors. To assess each corridor, the individual hazard ratings for each county along the corridor are averaged by length of the corridor contained in that county. The resulting value for each hazard type is then average to provide an overall all-hazards corridor rating.

Highway System Assessment Results

Ten primary corridors were identified for the Texas highway freight transportation system. Eight corridors were considered established freight corridors with significant volume of existing truck traffic. Two corridors, US 59/281 and the Ports-to-Plains corridor are classified as important, emerging corridors for highway traffic in Texas.

The overall highway system assessment for preparedness concludes that **the Texas highway corridors are highly resilient when considering robustness and redundancy**. This is evidenced by the low overall hazard risk ratings, relatively few physical constraints and limited areas of operational constraints on the primary and secondary routes.

Overall Statewide Highway System Assessment Results					
Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
Statewide					
Primary	4,550	2,000 to 10,800	2.8	23	Some
Secondary	9,650	1,000 to 12,600	Similar	38	Some

Source: TranSystems.

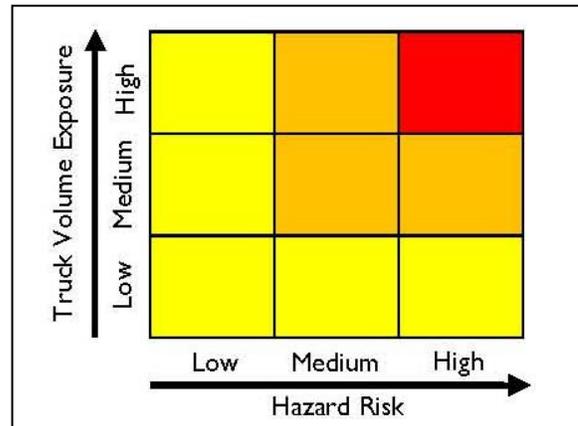
While the assessment of preparedness for the statewide highway system is positive, there is still a need to continually improve the system. One way to prioritize the corridors for future investments to increase their robustness and redundancy is to review the

overall hazard risk versus truck volume exposure. A risk vs. exposure matrix is used to prioritize based on where the data point falls in the matrix. For instance, it is undesirable to be in a high hazard, high exposure situation (upper right corner) and data points falling in this area may receive the highest priority. Data points that fall in the lower left corner are low hazard, low exposure and may not have as critical needs related to freight resiliency.

Using IH 30 as an example, the truck volume over the entire corridor is 8,200. Some segments of this corridor have higher volumes, others are lower. The overall hazard rating is 3.4. The hazard ratings range from 1.6 for wildfire to 5.7 for flood. The overall rating for this corridor falls in the high exposure, medium risk category.

Four highway corridors in Texas fall in the high exposure category: IH 45, IH 35, IH 20, and IH 30. No corridors fall in the high risk category. Two corridors fall in the medium risk category: IH 35 and IH 30. Other corridors fall in the upper end of the low risk category.

Using the risk vs. exposure plot, it appears that IH 35 and IH 30 should receive high priority for corridor improvements, as they have the highest risk and exposure combination of all Texas highway corridors (high exposure, medium risk).



Rail System Assessment Results

As private, profit-driven companies, railroads depend on reliable service to attract and retain customers. To ensure service for their customers, planning to eliminate or minimize service disruptions is considered to be an integral component of daily operations.

The overall rail system is highly resilient out of necessity. Railroads cannot let damage to their system impact their operations for extended periods or they will lose customers. They employ many methods during resiliency events including preparedness functions and recovery.

To prepare, railroads evacuate equipment and personnel while prepositioning materials, supplies, and equipment needed for repairs. During recovery they may utilize rerouting on their own system or on another carrier through track right agreements, while emergency repairs are conducted. In some cases, these agreements allow for a redundant rail network capable of responding to disruptions of virtually any duration.

While the railroads interviewed as part of this plan welcomed appropriate levels of assistance from TxDOT, their main request was assistance with overall emergency management coordination. Railroads rely on electricity to ensure safety, as well as to operate communication, signal, and highway-rail at-grade crossing systems. As part of emergency coordination, railroads requested that utility companies be made aware of this need and consider giving railroad companies priority when maintaining and restoring power. Additionally, communication with law enforcement was noted as important during recovery functions in order to allow emergency rail crews to access tracks when public roads are closed.

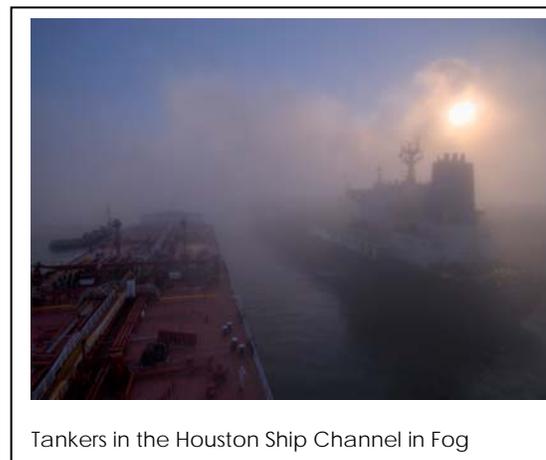
Other Mode Assessment Results: Marine, Air, Pipeline

Similar to railroads, other modes that are owned and operated by private companies are highly resilient out of necessity. However, this assessment also showed that in the case of the Port of Houston, the surrounding public roadway infrastructure is also highly resilient during events that cause abnormal fluctuations in truck traffic.

Representatives of the marine, air and pipeline modes that were interviewed as part of this plan indicated that coordination by all affected agencies is critical during events. One terminal operator noted that all mission critical personnel required to bring a terminal back on-line should be given an identification



Hurricane Ike Damage to Galveston Causeway



Tankers in the Houston Ship Channel in Fog



card that would allow them to pass through roadblocks or road closures during the terminal start-up phase. Not all of these mission critical employees have the required identification to get to the terminal if necessary. TxDOT personnel are often responsible for road closures but rely on local and state law enforcement to monitor compliance with the closures.

This request parallels that made by railroads suggesting that communication between the freight transportation community and law enforcement/emergency management agencies is critical to maintaining a highly resilient transportation system.

Advancing the Resilient Freight Transportation System

The interstate system and major US highways are the key corridors that carry truck-based freight. The state's highway infrastructure provides a robust and redundant system. However, the highway system is only one component of the overall freight transportation system that carries freight in Texas. The network of railroads, marine ports, airports, and pipelines complete the overall system. These other modes have shown they are highly resilient by their ability to swiftly recover from past events.

While the overall freight transportation system in Texas was found to be robust and redundant, there are actions that TxDOT can take in a continued effort to improve freight resilience in Texas. Based on the research completed and interviews with other states and the private sector, four strategies for advancing the resilient freight transportation system were developed.

Strategy 1: Support planning for a resilient, well-maintained freight transportation network

- Incorporate freight resiliency into traditional transportation planning and programming
- Include other modes in planning efforts to increase awareness of system-wide needs

Strategy 2: Prioritize infrastructure enhancements to improve the freight resilience of Texas highways

- Utilize corridor assessments to identify operational bottlenecks and physical constraints
- Investigate ways to fund improvements needed for other modes

Strategy 3: Improve access to data, information, and people needed for effective resiliency planning

- Understand baseline data and continue to build information database
- Define local issues and needs
- Recruit key players to boost effectiveness of planning

Strategy 4: Communicate before, during, and after events

- Provide up-to-date, comprehensive status reports
- Hold coordinating meetings among critical sector groups
- Engage the private sector

Approach for Future Stages

The Stage 2 SFR Plan should build on the recommendations of stakeholders to develop the necessary communication and implementation plan, to provide a resilient transportation system during and after an event. Stage 2 should also investigate ways



that TxDOT can expand its coordination efforts with state emergency management agencies to consider the needs of freight.

Stage 3 is an on-going, internal function for TxDOT. Continuous feedback after real events will improve the plan and ensure its relevance. After an event, freight considerations should be included in summary reporting so that efforts are documented and lessons drawn from the experience. In the absence of an event, TxDOT should continually evaluate resilience on a regular schedule and incorporate feedback so that consideration of the Texas economy stays in the forefront.

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Section 1. Introduction

As the twelfth largest economy in the world and the second largest in the United States, a resilient freight network in Texas is important to the economic health of the State and the nation. Each day millions of dollars of freight move into, out of, and through the state on highways, railroads, water, and air. Ensuring that the movement of these goods, in the face of an event, whether a hurricane, terrorist incident or infrastructure failure, is important not only to Texas but national and international interests.

The Texas Department of Transportation's (TxDOT) recognized that the highway system is a major component of a resilient freight network. As the managing organization responsible for maintaining the State's highways, TxDOT developed this plan to provide a comprehensive framework for identifying key freight infrastructure corridors and strategies to ensure a resilient freight transportation network in the State of Texas.

Definition of Freight Transportation System Resilience

Resilience is a term that is used by industry and government in a host of different applications. Resilience is a concern for business as it relates to their supply chain's ability to recover from a disruption. More commonly called business continuity planning, most private industries have plans in place to continue operations in the case of an unforeseen event. These plans incorporate analysis of existing operations, threats, and disaster scenarios along with identification of recovery tools such as communication systems and secondary work sites. Plans include implementation strategies and maintenance features.

Only until recently has the resilience term been applied by state departments of transportation (DOTs) to their transportation networks. This application is less clear as it has not been widely researched or applied to public institutions. However, current research, primarily completed for the Washington Department of Transportation, has outlined a definition and provided baseline information on resilience for the freight transportation system.

The currently accepted definition for **freight transportation system resilience** is **"the ability for the system to absorb the consequences of disruptions, to reduce the impacts of disruptions and maintain freight mobility."** (1) This definition is introduced in this plan as the baseline definition and is expanded in subsequent sections to address specific elements of the plan.

Approach and Process

The approach to developing the Texas Statewide Freight Resiliency (SFR) Plan considers national, state, local, and private plans for infrastructure protection, emergency management, and incident response. Research into these individual plans suggests a common approach to systematically develop a resiliency plan: prepare, detect, respond, and recover. This approach, as presented, appears simple but as the various

managing organizations, users, and infrastructure elements are considered the overall plan grows in complexity and must be tailored for Texas.

Considering the complexity involved in developing a resiliency plan, the Texas SFR Plan progresses in stages as illustrated in Figure 1. The stages are phased to accommodate the more familiar prepare, detect, respond, and recover approach. Stage 1 is focused on an assessment of the freight system's preparedness from the perspective of TxDOT as the managing organization. Stage 2 is associated with communication and plan implementation during response to an actual event and its recovery. Stage 3 incorporates a continuous feedback loop that recognizes that change is ever present and the plan must be updated on a regular basis to remain effective.

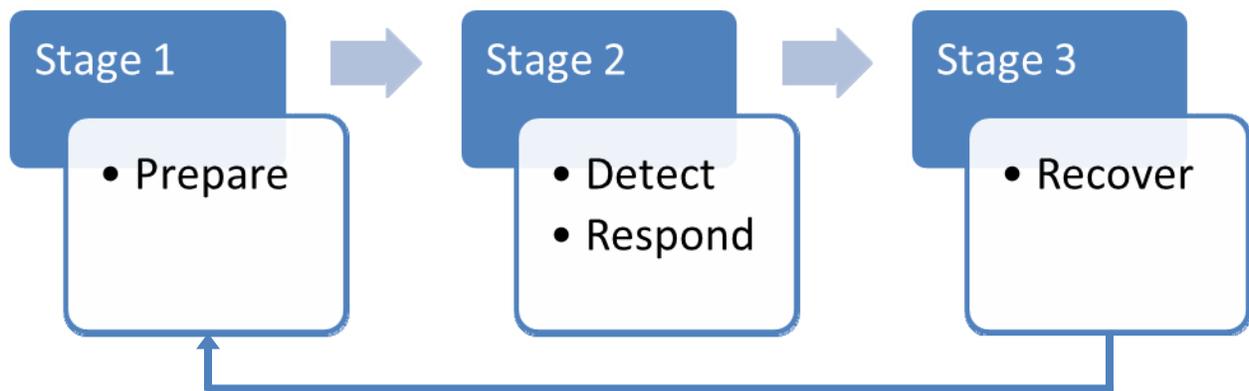


Figure 1. Texas SFR Plan Stages

Source: TranSystems

Purpose and Goals

The purpose of the SFR Plan was established by TxDOT with support from the Texas SFR Plan Advisory Committee. Three goals were developed to support the plan purpose. The purpose and goals guide the plan and are structured to follow the stages outlined in the Approach and Process.

The purpose of the Texas Statewide Freight Resiliency Plan is to assess the resilience of the strategic freight system in Texas when an event of extended duration limits freight mobility, resulting in prioritized infrastructure enhancements to keep freight moving.

Stage 1 Goal: To have a freight transportation system prepared to keep freight moving during an event.

- Provide redundant corridors clear of vertical, lateral, and load restrictions with reasonable capacity to detour freight during an event.
- Provide robust corridors when detour routes are unavailable.
- If redundancy and robustness are not feasible, then outline predictive information to relay through targeted communications channels.



Stage 2 Goal: To have a responsive framework to address shipper and carrier needs as an event occurs, and to recover the freight transportation system as quickly as possible.

- Institute a communications network targeted to sending messages to shippers and carriers.
- Rapidly return the freight transportation system to normal operations by deploying all available and appropriate resources in coordination with the appropriate chain of command.

Stage 3 Goal: To have a flexible, relevant plan that is used to improve freight mobility in Texas.

- Identify funding to implement infrastructure solutions that increase the robustness and redundancy of the freight transportation system.
- Build partnerships with emergency management to ensure that economic considerations are appropriately incorporated into response and recovery.
- Evaluate resilience on a regular schedule and incorporate feedback into plan updates.



Stage 1 Plan Outline

The Texas SFR Plan Stage 1 focuses on three areas:

- *Context and Purpose*: defined through literature research and interviews with key stakeholders and other organizations developing similar plans.
- *Freight System Identification*: identified using transportation system network and economic data.
- *Freight System Assessment*: assessed for physical and capacity constraints as well as understanding institutional and supply chain needs.

The Stage 1 Plan is organized into sections. Section 1 introduces the purpose of the plan. Section 2 provides context for understanding resilience and the framework as it applies to TxDOT. Section 3 details the importance of freight in Texas through a discussion of commodities and modes that leads to an identification of the freight system. Next, section 4 defines the freight system in Texas from a corridor perspective. Using the defined corridors, Section 5 assesses the preparedness of the Texas freight system in the context of resilience. Section 6 discusses strategies to advance the resilient freight transportation system in Texas. Finally, Section 7 summarizes the next Stages of the freight resiliency planning process for Texas.

In the future, Stage 2 will develop the necessary communication and implementation plan and test what is developed in the response and recovery phases of a simulated event. Stage 3 is an on-going, internal function for TxDOT to complete when the initial plan is finalized. Continuous feedback and improvement of the plan after real events will improve the plan and ensure its effectiveness.

Section 2. Understanding Resilience

TxDOT's interest in a resilient system for freight transportation stems from the knowledge that TxDOT plays a key role in the uninterrupted movement of goods. The following review of the state of the freight resiliency practice provides context to this plan in relation to national, state, local, and private methodologies for ensuring a resilient network.

National Efforts in Resilience

On a national level, resilience is primarily considered a responsibility of the Department of Homeland Security (DHS) and Federal Sector-Specific Agencies such as the Federal Emergency Management Agency (FEMA) and the Transportation Security Administration (TSA), in collaboration with the US Department of Transportation (USDOT). DHS has developed the National Infrastructure Protection Plan (NIPP) to provide "the unifying structure for the integration of existing and future critical infrastructure/key resources (CI/KR) protection efforts and resiliency strategies into a single national program to achieve this goal." (2)

The NIPP provides a risk management framework to promote continuous improvement to CI/KR. The framework as shown in Figure 2 focuses on a set of activities intended to enhance CI/KR protection. The activities outlined in the NIPP framework were referenced when the staged goals for the Texas SFR were developed. DHS stresses in the NIPP that its partners share responsibility for implementing CI/KR protection. Even though the NIPP heavily focuses on terrorist threat, it does acknowledge that CI/KR are vulnerable to other events. Considering the more broad approach to event-based risk, the Texas SFR Plan recognizes the NIPP as a guiding document and a valuable collaborative tool.

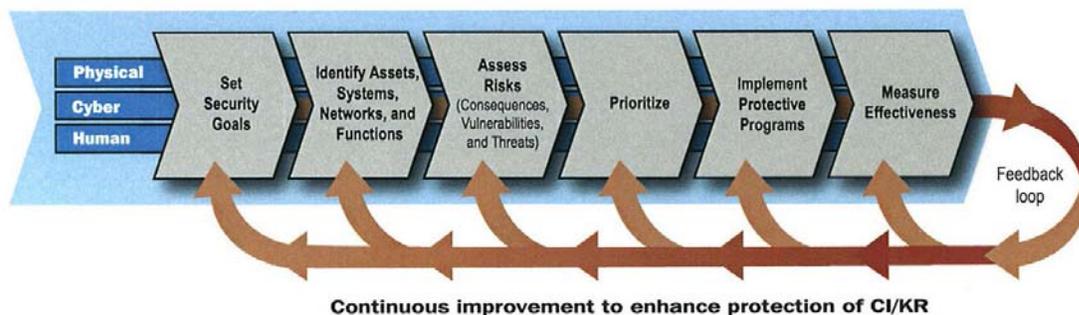


Figure 2. NIPP Risk Management Framework

Source: Department of Homeland Security.

Complementary to the NIPP are the National Response Framework (NRF) and National Preparedness Guidelines (NPG). The NPG presents guidelines for an all-hazards approach to preparedness. It sets the national priorities, roles, and responsibilities for a systematic approach to preparedness. The NRF is a guide to conduct all-hazards



response. It is a “scalable, flexible, and adaptable” structure and mechanism for national-level policy directing domestic incident management. The National Incident Management System (NIMS) works with the NRF to provide the template for the management of incidents. (3, 4, 5)

These national-level documents focus on policy, roles and responsibilities, and management of incidents. The American Society of Engineers (ASCE) takes a different path in reviewing national infrastructure resilience through its 2009 Report Card for America’s Infrastructure. The ASCE Report Card assesses the state of the infrastructure, reports on its condition and performance, and advises on the steps necessary for its improvement. Although the report card is not a national directive, it provides relevant information regarding resilience of the transportation system at a national level. (6)

Past report cards featured a security category to rate the ability of infrastructure to meet man-made threats. In the 2009 report, security was changed to overall resilience since risk of a natural disaster is higher, and resilience is determined on a system by system basis. The current definition of resilience provided by ASCE is “the capability of the system to prevent or protect against significant multi-hazard threats and incidents and the ability to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security.” (7) It is important to note that ASCE recognizes the economy in their definition which supports TxDOT’s reasons for developing the SFR Plan.

The ASCE Transportation report cards (6) include an assessment of bridge, rail, and road resilience based on risk and consequence management; life-cycle maintenance; sector and system interdependencies; and time, ease, and cost of recovery. ASCE reports that the overall national bridge system is highly resilient. They point to system redundancy as a key reason that the bridge system is resilient. The report card rating for rail resilience is not as positive due to the lack of redundancy, intermodal constraints, and lack of adequate investment. The road report card notes that the intent of the Interstate Highway System as a strategic, defense system directly serves the objective of resilience.

Although the Texas SFR Plan does not evaluate inland waterway systems, ASCE does have a report card for inland waterways. They report that the current system of inland waterways lacks resilience. The average facility has exceeded its design life, and the deteriorating system would make recovery difficult.

ASCE also prepared the document “Guiding Principles for the Nation’s Critical Infrastructure.” In this report, redundancy and resiliency of critical infrastructure is discussed. “Backup systems” to help mitigate critical infrastructure failures are recognized as redundant systems. A backup system refers to secondary infrastructure and other strategies to mitigate risk. The report points to resilient critical infrastructure systems as able to withstand and recover from extreme conditions and more rapidly recover than a non-resilient system. (8)



The report recognizes that developing a resilient critical infrastructure system is costly, but is likely far less costly than disaster mitigation. The report suggests that an “additional \$2 billion investment in the levees surrounding New Orleans may have reduced the tragic loss of life caused by Hurricane Katrina.” This suggestion illustrates that investment in preparedness has value and provides support to the overall purpose of preparing the Texas SFR Plan.

State Efforts in Resilience

Most state efforts focus on disaster preparedness, hazard mitigation or incident management with a focus on life and safety; relatively few use the term resilience in their documentation. As state plans are updated to reflect and coincide with national directives, it is likely that the term resilience will become more prevalent. State plans are mainly developed by state homeland security or emergency management agencies. Coordination with other agencies, like the Department of Transportation, is common and recommended in most plans.

The Washington State Department of Transportation (WashDOT) is currently viewed by many as leading the practice of statewide freight resiliency planning and implementation. A research report commissioned by WashDOT outlined steps to take when developing a statewide freight system resiliency plan. The report, prepared by the Massachusetts Institute of Technology’s (MIT) Center for Transportation and Logistics (CTL), concluded that a standard freight system resiliency plan is not appropriate as each state has unique qualities: freight moves in different economic patterns, each state’s risk profile for disasters differs from earthquakes to hurricanes, among others. Additionally, the authors stress that “the specific cause of the disaster is less important than the effect it has on the state’s transportation infrastructure network.” (9) This research sets the groundwork for WashDOT’s continuing efforts in developing the state of the practice in statewide freight resiliency.

On-going research sponsored by WashDOT has identified the definition for freight resiliency, various sets of threats imposed on DOTs, and operational and infrastructure components. Specific elements of this research are discussed in the following sections of the Texas SFR Plan as they directly relate to the development of a specific plan for Texas.

A series of interviews with peer state DOTs were conducted to gather information on current and best practices as well as determining the context for how other states are addressing freight resilience. DOT representatives from Washington, California, and Minnesota were interviewed.

The benefit of the WashDOT interview was that it clearly identified that Texas infrastructure is different from Washington. Texas has numerous redundant routes unlike the network in Washington; however, in situations where a redundant route is not available, WashDOT’s emphasis on the value of predictive information is important to consider. WashDOT’s information helped to develop the Stage 1 Goal’s of this plan.



While California has not completed any specific freight resiliency planning, the DOT representatives discussed redundancy and robustness as important attributes of a resilient transportation infrastructure. California's experience with natural disasters, primarily earthquakes, has required them to build robustness into their infrastructure through seismic retrofits. While California has not formally undertaken any resiliency planning, the efforts they have made confirm that Texas' focus on the resilience of the freight transportation system is important.

The Minnesota DOT (MnDOT), like California, has not formally completed any freight resiliency planning. However, they have experienced events that have required them to be resourceful in utilizing their infrastructure. They are willing to utilize the infrastructure in ways not originally intended to support an "emergency" use – driving on shoulders and shutting down intersections. Communication was also reported as an important component to successfully returning operations to a normal state. Much of the information gathered from MnDOT centered on response and recovery which is not the focus of the Texas SFR Stage 1 Plan; however, the information obtained will help direct future stages of resiliency planning in Texas.

Related Texas Plans

Research efforts on resilience applied in Texas resulted in limited direct information that would be applicable to developing the Texas SFR Plan. However, numerous state agencies, Metropolitan Planning Organizations (MPOs), Council of Governments (COGs), and counties/municipalities do have hazard mitigation plans, action plans, readiness plans, and/or evacuation plans in place. Most of these plans are intended to meet federal and state planning requirements and follow similar methodologies.

The plans reviewed mainly point to natural or weather-related hazards as the most common events impacting Texas. Most of the plans include risk assessment, hazard analysis, vulnerability assessment, and capability assessment. Each plan has a stated purpose and some plans, like the Alamo COG, list reducing potential future damages and economic loss as a priority. Even though the focus is not directly on freight, economic-related priorities do align with the reasons supporting the initiation of the Texas SFR Plan. (10)

The Travis County Hazard Mitigation Plan (11) identifies flooded roads as a significant problem and identifies the mileage of city-maintained, county-maintained, and state-maintained roadways located in the floodplain. It also maps numerous low water crossings in an attempt to raise awareness of these deficiencies because an increasing number of vehicles use these crossings due to new development. A specific action of the plan is to communicate road and bridge safety concerns to the appropriate agency, i.e. TxDOT. Actions, like those outlined in Travis County, are valuable input to the Texas SFR as they relate directly to identifying physical constraints that should be addressed to create a more resilient transportation network.

Supply Chain Resilience

Management of supply chain disruptions for private companies has become more prevalent in the wake of major natural disasters and terrorist attacks. Hurricanes Katrina

and Rita and the terrorist attacks of September 11, 2001 heightened the focus on building a resilient supply chain. It is important for a DOT to understand supply chain management during a disruption because supply chains depend on the physical infrastructure managed by the DOT. With respect to freight resilience, a DOT must consider how the transportation system is used by the private sector to effectively provide a resilient network.

A formal definition of supply chain management states “supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements.” (12) Supply chain management emphasizes a systems approach and considers the impact of decisions upon the entire chain. A key component that emphasizes the transport components is logistics management. As defined by the Council of Supply Chain Management Professionals (CSCMP), “logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements.” (13)



Figure 3. Illustration of Import Supply Chain

Source: TranSystems.

Professor Yossi Sheffi of the MIT CTL has completed extensive research on supply chain resilience. His book, *The Resilient Enterprise* (14), reviews corporate preparedness as a competitive advantage to business. Through his research, Sheffi suggests private industry use several methods to decrease vulnerability and increase flexibility. Companies can become more resilient by improving supplier relationships, enhancing communication and collaboration, and changing production operations.

UPS developed a white paper titled “Supply Chain Resilience: How are Global Businesses Doing?” This white paper highlighted that the key to a successful supply chain is to “build in resilience, understand the issues, monitor and structure the supply chain to avoid problems, and work with suppliers to improve output.” (15) One participant in the UPS project indicated that “it is difficult to afford redundant infrastructure, but you can build the supply chain in a way that you can use other parts if some fail, and so that there are people to call on if you have to scramble.” This statement illustrates that a redundant transportation system provided by a DOT is an important element to a resilient supply chain even though it may not be explicitly indicated in a private sector plan.



“Interpreting Resiliency: An Examination of the Use of Resiliency Strategies within the Supply Chain and Consequences for the Freight Transportation System” discusses the relevance of supply chain resilience to the transportation system. (16) This research indicates that the private sector may have a plan in place but that plan is not effective unless information or infrastructure is available. The level of resilience of a supply chain during a disruption will be highly dependent on information related to infrastructure impacts, i.e. port or border closures. Information exchange is also suggested as a critical requirement before, during, and after a disruption. This research illustrates that the infrastructure managed by TxDOT and the infrastructure needed by users is interdependent and interaction is necessary for both to achieve resiliency.

Globalization of supply chains increases vulnerability to disruption by natural and man-made incidents. What may seem like a small, localized disruption can impact an entire company’s operation. Through the development of the SFR Plan, TxDOT recognized the greater economic impact that a disruption in the transportation system has on global business. The research presented reinforces that communication, redundancy, and collaboration are critical to freight system resiliency for both TxDOT and private industry.

A Resilience Framework for Texas

At the national, state, local, and private levels it is apparent that resilience in its broadest definition – the ability to recover to the original or an improved state – is important for economic health. However, there is no specific framework available that clearly defines how a state DOT can measure or ensure a resilient transportation system. All of the previous listed research helps clarify definitions and supports reasons to pursue resiliency. A framework specific to the Texas SFR Plan will draw on elements of other research.

Defining the Resilience Triangle

In developing a framework specific to Texas, it is first important to clearly set out definitions for related terms: freight transportation system resilience, event, incident, disruption. It is with these definitions that a clear focus is set for the plan. These definitions can best be explained in the context of the “resilience triangle” shown in Figure 4. The resilience triangle plots the quality or functionality of infrastructure after a loss. (17)

As stated earlier, the definition for **freight transportation system resilience** is the ability for the system to absorb the consequences of disruptions, to reduce the impacts of disruptions and maintain freight mobility. The resilience triangle helps to define the stages of a resilience event. An **event**, in the context of the Texas Stage 1 SFR Plan, is overall occurrence or the complete cycle illustrated in the resilience triangle. In this plan, the overall event and the specific incident are not interchangeable. The **incident** refers to the specific action that occurs at a defined point in time that triggers a change in the transportation system. For instance, an incident is when the hurricane makes landfall but the event is everything from evacuation to restoring power to providing emergency services to those impacted by the storm. The incident is represented by the star on the resilience triangle in Figure 4.

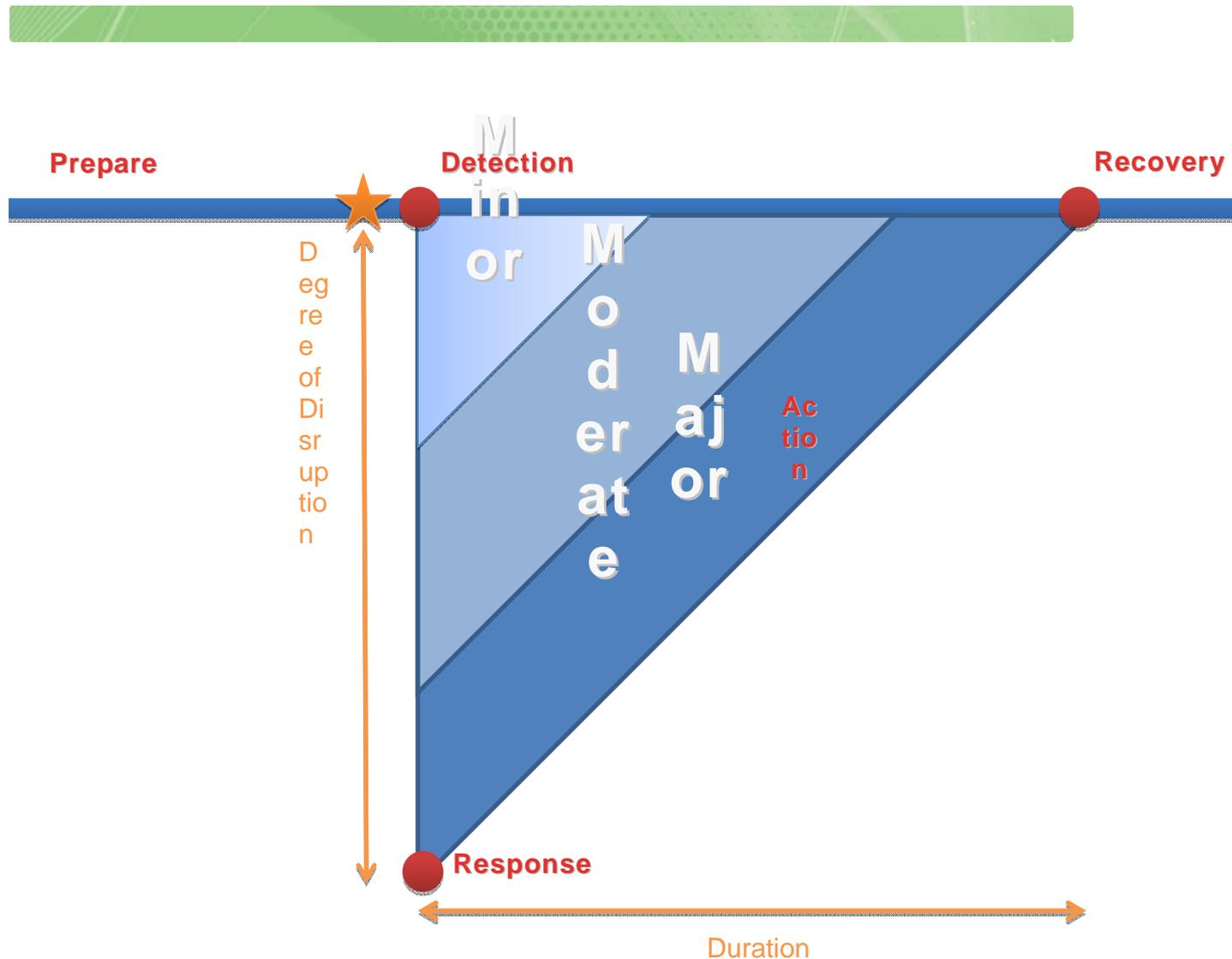


Figure 4. Resilience Triangle

Source: TranSystems derived from Multidisciplinary Center for Earthquake Engineering Research (MCEER).

Disruption is what occurs when the incident happens, i.e. a highway is closed due to mudslide or a rail line is out of service due to flooding. The **degree of disruption** is measured as minor, moderate or major based on the duration of time it takes to detect, respond, and recover from the incident. The **duration of disruption** can vary depending on the severity of the incident. A traffic accident may shut down a roadway for several hours or a major earthquake may shut down a roadway for several months to make repairs. The Texas SFR Plan is interested in disruptions that are of a longer duration – moderate to major. Disruptions that cause a change in freight travel patterns are the focus rather than a short-term or minor closure where a driver may just “wait it out.”

Another way to understand the focus of the Texas SFR Plan is to define the spectrum of events. Events can be recurring, episodic or catastrophic. **Recurring events** such as traffic congestion are routine and freight shippers and carriers are aware of these constraints. **Catastrophic events** result in extraordinary loss of life and property. These



events cause national-level impacts over prolonged periods that exceed capabilities of normal resources. The Texas SFR Plan will focus on episodic events. An *episodic event* is an unpredictable occurrence yet manageable with available resources.

The resilience triangle is sequenced to follow the timeline of the event from normalcy through detection, response, recovery, and back to normalcy. The goal of a resilient freight transportation system is to reside in the “normal” stage of the event cycle. Due to the possibility of disruptive events; however, planning should occur for all stages. Stage 1 of the Texas SFR Plan will focus on the pre-incident stage where the attention is on preparedness.

Dimensions of a Resilient Freight Transportation System

Along with understanding the resilience event cycle, it is important to understand the dimensions of the freight transportation system. Researchers at the University of Washington point out that a resilient freight transportation system has three major dimensions: the physical infrastructure, users, and managing organizations. (7)

The physical infrastructure is represented by highways, railroads, bridges, ports, and all other assets. These are the traditional elements that are considered part of the freight transportation system. The Washington researchers report that resilience of this dimension is the “ability of the network, given its capacity to supply lane miles, to facilitate the movement of goods under capacity-constrained conditions that are due to a disruption.” (7) In the Texas SFR Plan, the physical infrastructure dimension is approached not only from the capacity perspective but also the physical limitations such as dimensional or weight restrictions.

The freight transportation system users are represented by the vehicles operating on the network and the managers that direct their travel. Depending on the segment of the freight network being considered, the user has different constraints. Truck users operate freely on the roadway network while trains are more restricted and have less connectivity.

The managing organization is responsible for all aspects of the freight transportation system – operations, maintenance, and communication. A state DOT is the managing organization for the highway transportation network while the railroads are not only the user of the rail network but also the managing organization.

Figure 5 illustrates the three dimensions of the freight transportation system and their overlap. The Texas SFR Stage 1 Plan focuses on the overlap between the Physical Infrastructure dimension and the Managing Organization dimension. TxDOT has direct control over the roadway physical infrastructure and that management responsibility is the focus. However, the overall freight system is important to a resilient freight transportation system and understanding the role of other managing organizations (i.e., port operators, railroads) and users is necessary. Stage 1 discusses the role of other managing organizations and physical infrastructure. Future stages will focus on the overlap with Users of the system as communication is primarily interaction with users.

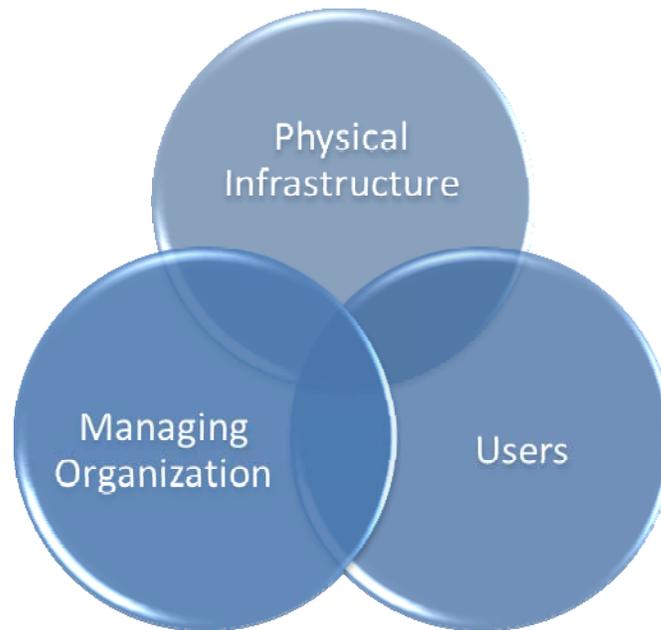


Figure 5. Dimensions of the Resilient Freight System

Source: TranSystems derived from University of Washington.

Attributes of a Resilient Freight Transportation System

Recognizing that an event is likely to occur at some point in time, the goal of a resilient freight transportation system is to minimize the size of the resilience triangle both in terms of degree of disruption and length of duration. MCEER developed the R4 Framework as measures to reduce the size of the resilience triangle by improving the infrastructure's performance and the time to recovery. (18) The measures in the R4 Framework are:

- Robustness
- Redundancy
- Resourcefulness
- Rapidity

A **robust** system is one that can withstand an incident without significant failure. In the context of the Texas SFR Plan, elements like weight restrictions on bridges or vertical clearance limitations are physical elements that limit robustness. A **redundant** system focuses on the availability of alternate routes or modes. In the case of a highway system, frontage roads can be considered an immediate redundancy but it is more likely that a US or State highway parallel to the Interstate is the redundant route that should be considered.

Resourcefulness is reflected in the ability to source material and other resources to restore operation. A resourceful managing organization may attempt to preposition heavy equipment immediately outside of a hurricane zone so that it is protected and can be mobilized quickly after the incident occurs. **Rapidity** is a function of the time needed to restore the system functionality.



When mapped on to the resilience triangle, attention to a robust and redundant freight transportation system occurs during the normal or preparedness stage. These elements of the R4 Framework focus on the actions that a managing organization takes on the physical infrastructure. Resourcefulness and rapidity occur from the point of detection to recovery and focus on the actions of the managing organization and the system users. Emergency management operations and communications are the primary focus of the managing organization and users during these stages.

Texas Framework Summarized

The Texas framework is built on definitions, dimensions and attributes of a resilient freight transportation system. Definitions are established to clearly outline the terminology of the SFR Plan. The dimensions outline responsibility for actions. The attributes highlight the timing of actions during the event cycle.

When all three are viewed together, the focus of the Texas SFR Stage 1 Plan is on moderate to major duration events that impact the physical highway infrastructure managed by TxDOT, considering robustness and redundancy of a resilient freight transportation system. Disruptions that are of a longer duration cause a change in freight travel patterns. TxDOT has direct control over the physical highway infrastructure and responsibility to manage it. Attention to a robust and redundant freight transportation system occurs during the normal or preparedness stage.

Furthermore, the overall freight system is important to a resilient freight transportation system and understanding the role of other managing organizations (i.e., port operators, railroads) and users is necessary. Stage 1 of this plan will discuss the role of other managing organizations and physical infrastructure. Future stages will focus on the overlap with responsiveness and resourcefulness as it relates to users of the system, as communication is primarily interaction with users.

Section 3. Freight in Texas

The importance of freight transportation to the economy of Texas, and the entire US, has grown over the last few decades. Freight transportation has become increasingly complex and its efficiency is essential to reduce cost of the overall supply chain. The economy of Texas is diverse and supported by an extensive transportation network of roadways, railroads, airports, and waterways.

Texas Economy

Texas is an economically diverse and dynamic state with a population of 24.8 million in 2009 (19) and a gross domestic product (GDP) of \$1.2 trillion in 2008 (20). Texas is the second largest state in the US by size of economy and population, accounting for nearly 9 percent of the country's GDP and 8 percent of its population. If Texas were its own nation, it would rank twelfth measured by GDP, ahead of countries including Mexico, Australia, South Korea, and the Netherlands.¹ Long term economic and population growth will place additional demands on the State's freight transportation infrastructure. Population is projected to expand to 33.3 million by 2030 based on interim projections released by the US Census Bureau.

The state's economic activity is heavily concentrated in a triangle connecting Dallas, San Antonio, and Houston, and covering four metropolitan areas. The Houston-Sugar Land-Baytown MSA and the Dallas-Fort Worth-Arlington MSA accounted for 33 percent and 31 percent, respectively, of the state's GDP in 2008 shown on Figure 6. The shares of the San Antonio and the Austin-Round Rock MSAs were each 7 percent. El Paso was the next largest MSA accounting for 2.2 percent.

Manufacturing and mining are the two largest contributors to state GDP, accounting for 13.0 percent and 11.3 percent respectively. Other sectors that generate or support freight movements account for a further 21.1 percent of GDP - wholesale trade, retail trade, construction, transportation and warehousing, agriculture, and forestry. (20)

Texas is one of the largest agricultural producers in the country and, for example, ranks fourth in total value of agricultural exports. (21) While the agricultural sector accounts for only a small share of GDP, it does generate significant freight volumes – domestic shipments, commodities for export (e.g. cotton), and perishable commodities (e.g.

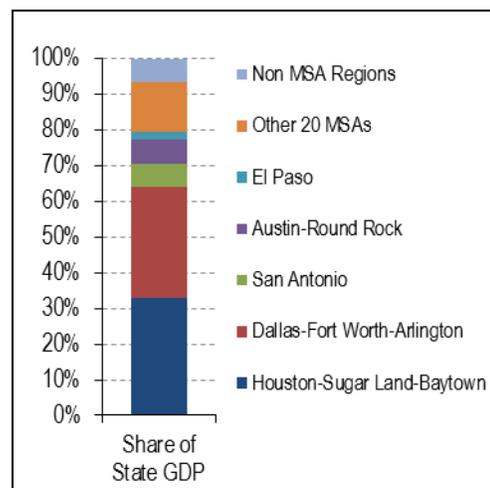


Figure 6. Texas GDP by MSA, 2008

Source: Bureau of Economic Analysis

¹ Based on 2008 data from the US Bureau of Economic Analysis and the International Monetary Fund



refrigerated meat) – that are sensitive to disruption to transportation infrastructure and service.

Freight System Overview

Highways

TxDOT, in cooperation with local and regional officials, is responsible for planning, designing, building, operating, and maintaining the state's highway transportation system. The state maintains nearly 79,700 centerline miles comprising of numerous roadway types listed in Table 1.

Roadway Type	Centerline Miles
Interstate Highways	3,233
US Highways	12,105
State Highways	16,354
Farm or Ranch to Market Roads	40,969
Frontage Roads	7,069
Park Roads	337

Source: Texas Pocket Facts 2009.

Texas has nearly 50,000 bridges which is nearly double the number of bridges of any other state in the nation. Approximately 18 percent of bridges are classified as deficient in some form. Over 1,600 bridges are classified as structurally deficient meaning they are limited in their load-carrying capacity or they frequently flood. Bridge load restrictions are particularly problematic to freight transportation as a standard over-the-road truck must change routes where limits are posted. Texas also has around 7,400 functionally obsolete bridges. These bridges do not meet current geometric design standards and do not efficiently handle today's traffic volumes and types. There are a further 1,200 that are substandard-for-load-only bridges; they are not structurally deficient or functionally obsolete but have a load capacity less than the maximum permitted by state law.

While only 26 percent of roadways in Texas are state-maintained, 74 percent of all vehicle miles traveled (VMT) occurs on state-maintained highways. The state system handles approximately 2.5 billion tons of trucked freight, a mixture of intra-state, inbound, and outbound shipments. (22) Of notable importance to the Texas economy is highway freight related to international trade through the state's marine ports and, in the case of both Texas and the national economy, freight flows along major highway corridors connecting to land border crossings. (23)

Texas highways provide the last-mile delivery of products to manufacturers and consumers, as well as, long-haul shipments in, out, and through the state. Disruptions to the highway network will impact huge quantities of goods and important industries in

the state. However, trucks have more flexibility in routing so ensuring network redundancy will lessen the impact.

Railroads

Texas has the country’s most extensive rail network with 10,743 miles of track and ranks second in total rail carloads (9.4 million in 2008). (24) The 2010 Texas Rail plan indicates that the system has 9,780 public highway -rail crossings.

Three major railroads – Union Pacific Railroad (UP), BNSF Railway (BNSF) and Kansas City Southern Railway (KCS) – operate 77 percent of the track and the remainder is operated by regional, local, switching and terminal railroads. Including owned and trackage rights, the three major railroads operate over 12,180 miles² of track, the UP operates over 6,331 miles, BNSF over 4,491 miles and KCS over 908 miles. All the major cities, marine ports, and border crossings are served by the rail network.

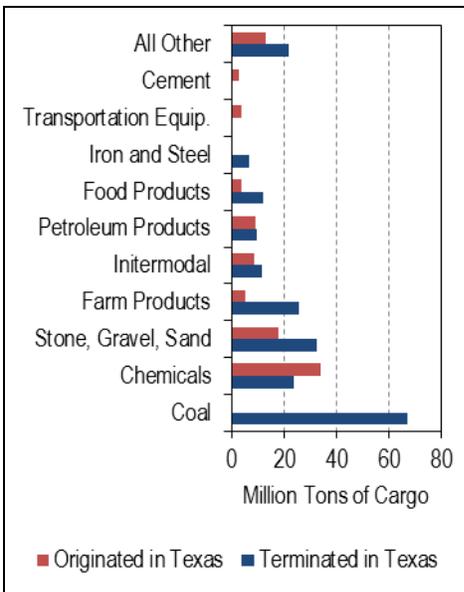


Figure 7. Rail Cargo in Texas, 2008

Note: Excludes rail traffic through Texas
 Source: American Association of Railroads

In 2008, 384.4 million tons of cargo originated, terminated or passed through Texas. Total terminated traffic was 210.3 million tons, originated traffic was 96.6 million tons, and through freight was 77.4 million tons. A significant share of through traffic is rail freight moving between the US and Mexico.

The principal commodities originated and terminated in Texas are shown in Figure 7. Coal is the largest commodity, feeding the electric utility sector. As a major center for the chemical and petroleum industries, chemicals is the second largest commodity group while petroleum products is also important. The agricultural sector generates significant volumes of freight, as does requirements for stone, gravel, and sand primarily from the construction industry.

Given the large volume of freight movements by rail in Texas, disruption to the rail network could have significant impacts on truck traffic volumes. The American Association of Railroads estimates one train can carry the load of 280 or more trucks.

² The American Association of Railroads reports Texas has 10,743 miles of physical track. It also reports that the major railroads operate on 12,180 miles of track in Texas. The difference is explained by trackage rights. A major railroad will operate on its own track but may also have the right to operate on track owned by another railroad.

Marine Ports

The Texas economy and its maritime trade are served by eleven port districts³, which moved 473 million tons⁴ of cargo in 2008 and 19 percent of the nation's port tonnage according to the US Army Corps of Engineers (USACE). The dominant cargo flow, as shown in Figure 8, is inbound international trade (55 percent of cargo tons) followed by outbound international trade (19 percent). The ports handled 353 million tons of international trade, 23 percent of the international trade handled by the country's ports, and 62 million tons of domestic cargo. The total also includes intrastate cargo, tonnage moving between ports in Texas, amounting to 59 million tons in 2008.

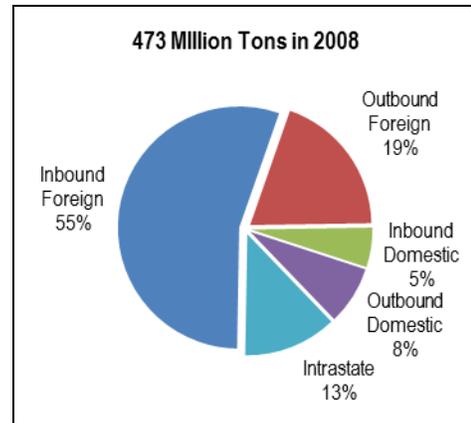


Figure 8. Texas Port Throughput

Source: US Army Corps of Engineers

Including all forms of cargo handling, Texas ports moved 503 million tons of cargo in 2008. The principal commodity groups were Petroleum and Petroleum Products (71.3 percent of total tons), Chemicals and Related Products (14.0 percent), Crude Materials (5.1 percent), Primary Manufactured Goods (3.7 percent), and Coal (0.1 percent). Texas marine ports can be grouped into four geographic areas, running from North to South:

- Sabine Lake, near the border with Louisiana. Ports are Beaumont, Port Arthur, and Sabine Pass, and they handled 20 percent of total tons.
- Galveston Bay and the Houston Ship Channel, a 43 nautical mile long navigation channel. Ports in this area are Houston, Texas City, and Galveston, and they handled 55 percent of total tons.
- The Gulf Coast from south of Galveston to Corpus Christi – Freeport, Corpus Christi, Matagorda, and Victoria. They had a 24 percent share of total tons.
- The border with Mexico – Brownsville with a 1 percent share of total tons.

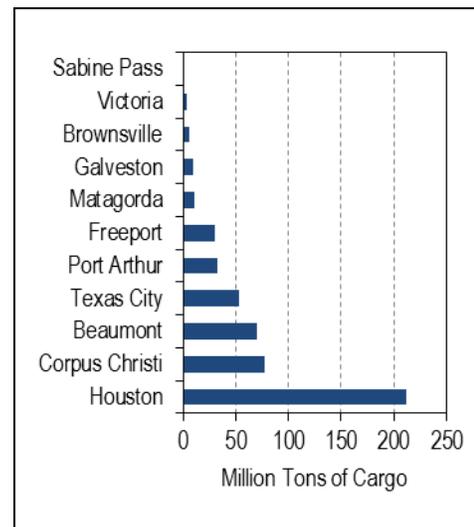


Figure 9. Cargo Tons by Texas Port

Note: Tons includes foreign, domestic, and intra-port

Source: US Army Corps of Engineers

³ The port districts defined by the US Army Corps of Engineers include public and private cargo handling facilities.

⁴ The State total (473 million tons) excludes double counting of cargo – for example, a ton of domestic cargo shipped from one port in Texas and received by another port in Texas is only counted once. The total based on summing individual ports (503 million tons) includes some double counting of cargo.

Texas has three of the country's top ten ports⁵ when measured by total tons – Houston (ranked second), Corpus Christi (fifth), and Beaumont (seventh). Houston handled 212 million tons in 2008 (Figure 9) followed by Corpus Christi with 77 million tons and Beaumont with 69 million tons. In addition, Houston ranks as the country's largest port when looking only at cargo moving in foreign trade. It's also noteworthy that the Galveston Bay/Houston Ship Channel port area, combining Houston, Texas City, and Galveston, would rank first in the country based on total cargo tons.

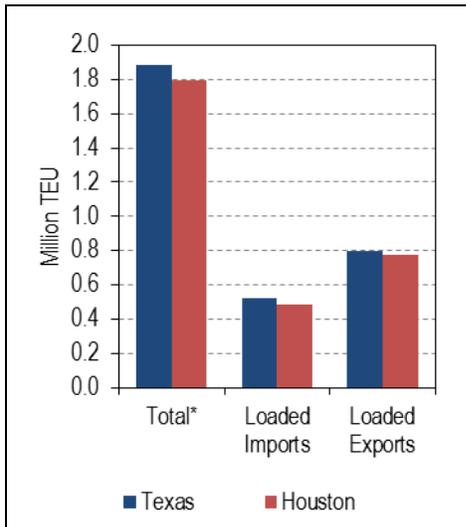


Figure 10. Container Port Throughput, 2009

* Loaded imports, loaded exports, and empty containers

In the higher value containerized trade, Texas ports had total throughput (loaded imports, loaded exports, and empty containers) of 1.9 million TEU in 2009, with 1.8 million TEU handled by Houston (Figure 10). Other ports in Texas with small volumes of containers were Freeport, Galveston, and Beaumont. In 2009, Texas ports handled 5.1 percent of the country's total container throughput, 3.6 percent of loaded imports, and 7.7 percent of loaded exports. Houston ranked as the country's sixth largest container port and the largest container port on the Gulf coast.

The Port of Houston is a major center for consolidation and deconsolidation of containerized cargo. Imported containers are trucked from the marine terminals to local warehouses, stripped, and the cargo is then trucked to its final destination using domestic

trailers. Alternatively, some imported containers are trucked further inland for warehousing and distribution. Similarly, cargo for export may be loaded into containers at inland locations, and then moved to the port, or the cargo is loaded in containers near the marine terminals.

Ports in Texas do not handle all the containerized cargo consumed in Texas or shipped from Texas. For example, many imports from Asia flow through the ports of Los Angeles and Long Beach, and then by intermodal rail service to markets in Texas. The expansion of the Panama Canal, currently scheduled for completion mid-decade, will allow larger ships to pass through the canal and may generate increased flows of containerized cargo through Houston and other ports in Texas.

Marine ports are an important part of the transportation infrastructure serving the Texas economy and the State's international trade. Within this marine port network, terminals on the Houston Ship Channel and Galveston Bay are of particular importance, handling 55 percent of total port throughput and 95 percent of the State's container throughput. Ports have medium- and long-term strategies to expand marine terminal capacity in

⁵ National ranks are based on 2008 tons published in the Waterborne Commerce Statistics, US Army Corps of Engineers. In 2008, the Port of South Louisiana ranked first with 224 million tons.



response to growth of the Texas economy and its maritime trade. Such expansion plans and increased cargo flows will generate additional freight moving to and from ports by highway and rail.

Given the national importance of Texas' marine ports, impacts to the ports during and after a disruption could have significant negative impacts on the national economy, not only Texas. Maritime shipping does not have a short-term substitute allowing for mode shift which would force shipments to divert to other ports capable of handling similar shipments. However, the absence of established inland infrastructure, particularly pipelines, at other marine ports makes diversion to other locations more complicated.

Gulf Intracoastal Waterway

The 1,300-mile Gulf Intracoastal Waterway (GIWW) is a shallow-draft navigation channel that connects ports along the Gulf Coast and provides these ports with access to the country's inland waterway system. In Texas, the GIWW extends for 423 miles from the Sabine River to the Mexican border (Figure 11). The GIWW in Texas handled 69 million tons of cargo in 2008, 43 million tons of petroleum and petroleum products, 17 million tons of chemicals and related products (both dry and liquid), and 9 million tons of dry cargo (e.g. food products and crude materials).

An estimated 70 to 80 percent of total freight moved on the Sabine River to Galveston segment, 30 to 40 percent on the Galveston to Corpus Christi segment, and less than 5 percent between Corpus Christi and the Mexican border.⁶ The GIWW passes under road and rail corridors at several locations namely in Galveston where it passes beneath IH 45 and the Galveston Island railroad bridge.

Barging of cargo is a cost competitive, efficient, and environmentally friendly transportation mode. One barge moving 1,750 tons of dry cargo is equivalent to 16 rail cars or 70 trucks⁷. For example, in 2008, 9 million tons of dry cargo handled by barge on the GIWW was equivalent to an estimated 82,000 rail cars or 360,000 trucks. Similarly, one barge moving 27,500 barrels of liquid cargo is the same as 46 rail cars or 144 trucks.

⁶ The shares sum to more than 100 percent because a cargo ton can move on more than one segment – for example one ton of cargo shipped from Sabine River to Corpus Christi is counted twice – once in the Sabine River to Galveston segment and once in the Galveston to Corpus Christi segment.

⁷ Reported in the study "A Modal Comparison of Freight Transportation Effects on the General Public" commissioned by the National Waterways Foundation.

Given the volume of freight moving on the GIWW, any sustained disruption, requiring diversion of freight from barge to other modes, could have significant negative traffic impacts on the highway and rail systems in Texas. The impacts are not only realized from potential mode shift but from the lack of fuel to operate as the GIWW supports the



Figure 11. Gulf Intracoastal Waterway in Texas

Source: TxDOT

commercial fuel industry's product availability (i.e, fuel stations).

Airports

The Texas airport system is one of the largest in the country with nearly 300 airports, including 27 commercial service airports. The two largest airports are Dallas-Fort Worth (DFW) International Airport and Houston's George Bush Intercontinental Airport. In 2009, DFW Airport was the world's third busiest measured by plane movements and was the eighth busiest airport in passenger numbers. George Bush Airport was the World's

seventh busiest in plane movements and ranked sixteenth in passenger numbers. In 2009, DFW Airport handled 56 million passengers and George Bush Airport 40 million. (26)

In 2009, DFW Airport handled 638,000 tons of air cargo, including 276,000 tons of international freight and George Bush Airport moved 409,000 tons including 170,000 tons of international air freight. (26) Air cargo is a very small segment of State freight flows; however use of air cargo services is very important to many shippers of high value and/or time sensitive products (pharmaceuticals, perishable food products, etc.). They are prepared to pay the higher rates charged by airlines to ensure the timely and secure delivery of products and components.

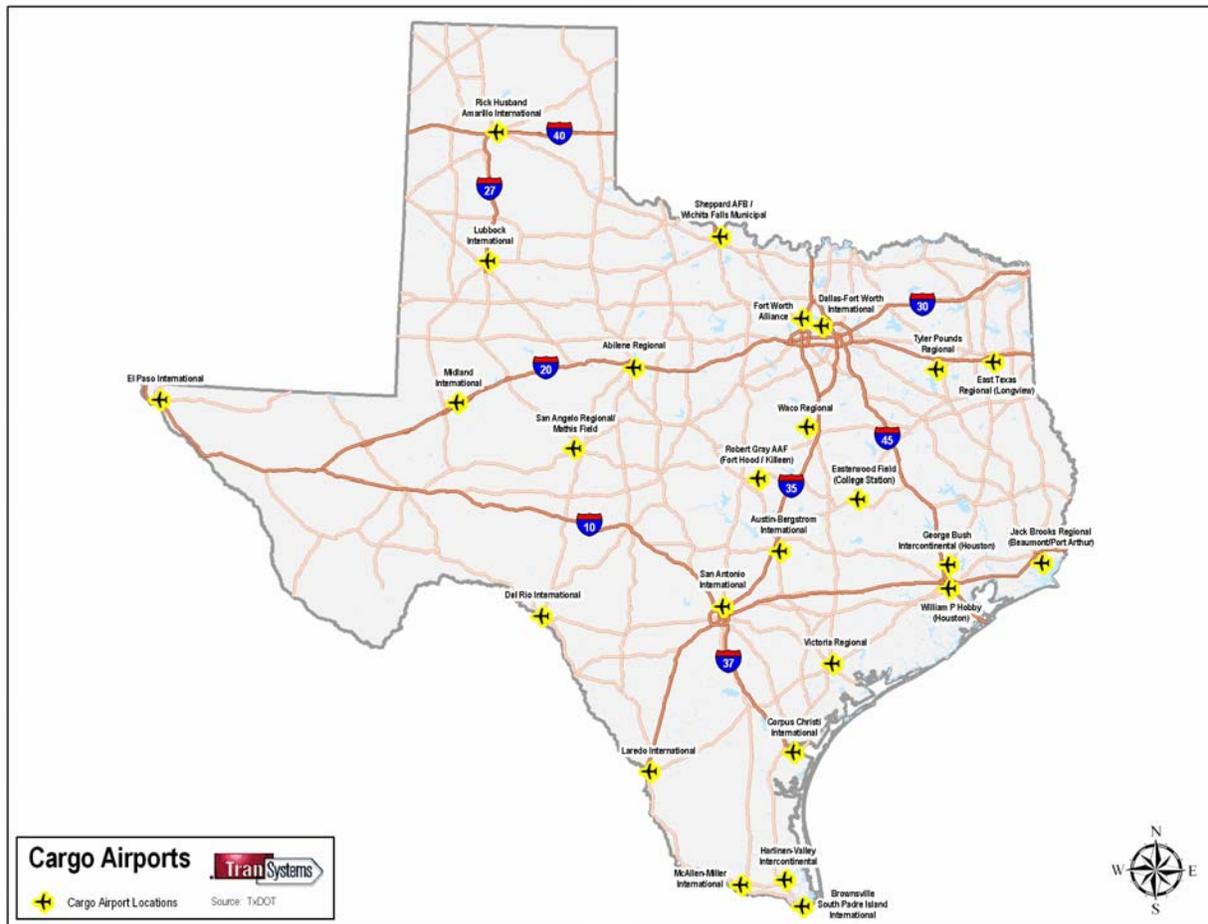


Figure 12. Commercial Service Airports in Texas
 Source: Texas Airport System Plan Update 2010, TxDOT

A disruption at one of Texas' commercial service airports would jeopardize the timely and secure delivery of high value and/or time sensitive products. Given the nature of these products, the next likely transportation option would be trucks which would add additional volume to Texas highways.

Border Ports of Entry

Texas is the primary gateway for US surface trade with Mexico, handling 75 percent of U.S surface trade, 71 percent of imports, and 79 percent of exports in 2009. (27) Trade with a value of \$180 billion flowed through Texas border crossings – 84 percent by truck and 16 percent by rail. Major freight lanes are with the border states of Mexico and the more southerly regions around Mexico City.

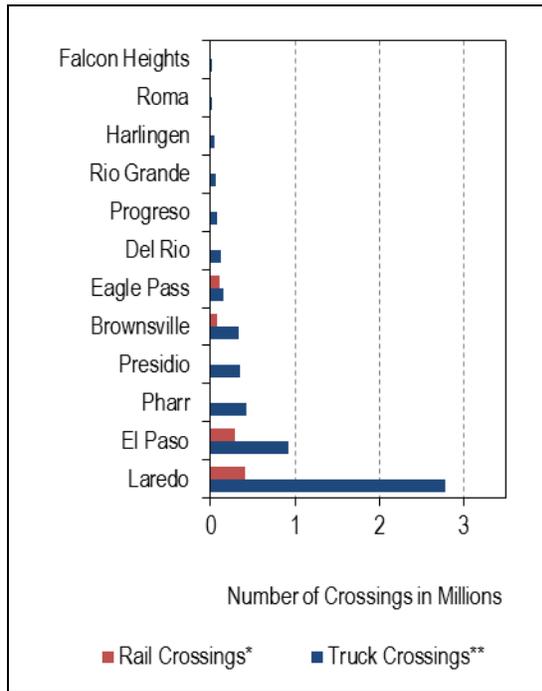


Figure 13. Border Crossings in 2009

* Comprised of rail-box crossings from all rail lines.

** Comprise all commercial vehicles crossing through international bridges (2, 3, 4, 5, 6+ axle).

Source: Texas Center for Border Economic and Enterprise Development

while El Paso is on the BNSF and UP rail system.

The busiest border crossing point is Laredo (IH 35), which had 2.8 million commercial vehicle crossings in 2009, as indicated on Figure 13. This volume was down from 3.2 million crossings in 2008 due to the economic recession's impact on cross-border trade. Other important crossings for commercial truck traffic are El Paso (IH 10), Pharr (US 281), Presidio (US 67), and Brownsville (US 83). The top five border crossings handled 91 percent of commercial vehicles and Laredo alone accounted for 53 percent.

The commercial cross-border truck traffic travels over Texas highways, notably the IH 35 corridor connecting Laredo with San Antonio, Austin, Dallas, and other States. US-Mexico trade flowing along this corridor adds to the already heavy traffic volumes from intra-state traffic.

Laredo is also the top border gateway for rail movements handling 403,000 rail-box crossings in 2009, with 46 percent of the total moving over the Texas border. Eagle Pass was the other main border crossing for rail traffic with a 33 percent share. Rail traffic travels on main north-south corridors provided by major railroads. Laredo is on major routes of the UP and KCS railroads,



Section 4. Process to Determine Resilience of the Texas Freight System

The process to assess the resilience of the Texas freight system was developed based on research presented previously and tailored to the specific needs of infrastructure in Texas. The process is flexibly designed in order to adequately conduct the assessment of the corridor under consideration. When reviewing a specific corridor, refinements to the process are expected to ensure that the most appropriate result is obtained.

The process follows the principles of a standard risk management procedure. Specifically for freight resilience planning, the freight infrastructure and hazards are first identified and then assessed. Once the assessment is complete, any constraints are mitigated and then prioritized. Finally, strategies are developed to guide the on-going, overall freight transportation system resilience efforts. This section of the plan focuses on corridor and hazard identification and assessment methodology.

Corridor Identification

The vast Texas freight system relies on infrastructure – highways, railroads, airports, and waterways – to carry goods from origin to destination and points between. The infrastructure used during normal conditions connects population, employment, and activity centers. These connections or corridors are the focus of assessing the Texas freight system.

The first step of the methodology for assessing the resilience of the Texas freight system is to identify the corridors and routes to analyze. TxDOT defines a corridor as “a broad geographical band with no predefined size or scale that follows a general directional flow connecting major sources of trips.” Trips are basically generated by population and employment. Data on population and employment by county was used as the basis for an initial identification of the geographical bands between major source points. Figure 14 shows the population and employment density by county based on US Census data from 2007.

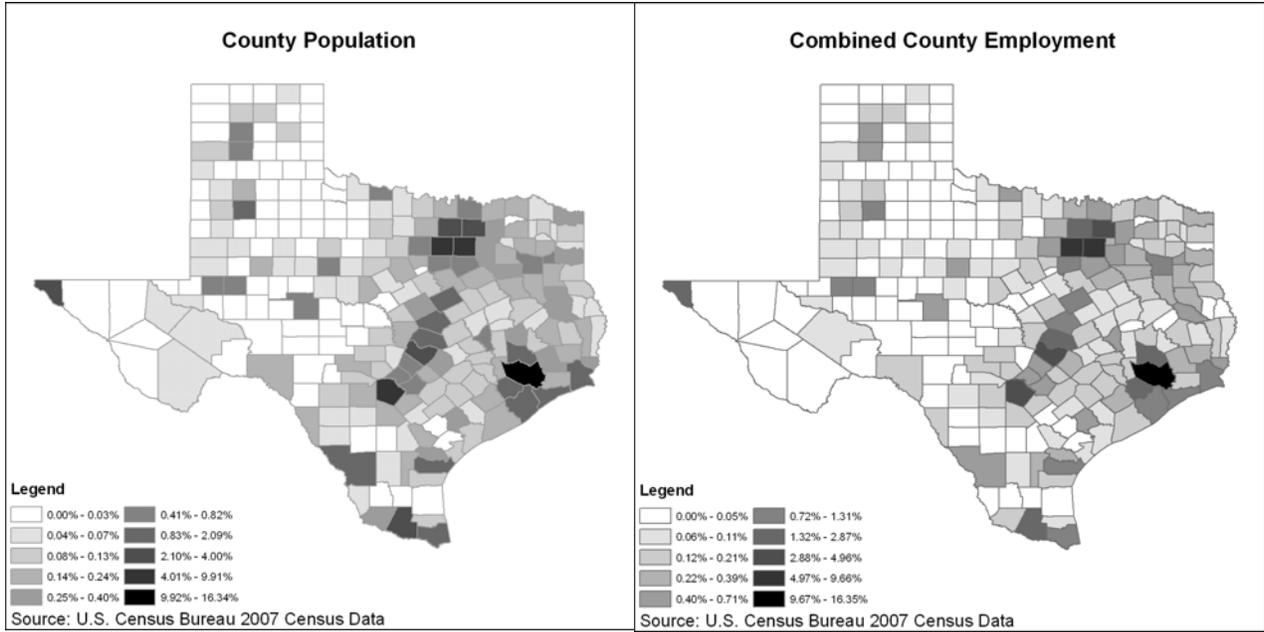


Figure 14. Population and Employment Density

Source: TranSystems derived from US Census Bureau.

Population and employment, the source of freight trips, is generally concentrated on the east side of the state. The "Texas Triangle" or the triangle connecting Dallas, San Antonio, and Houston sees the highest concentration. There are pockets in south and far west Texas with high concentrations but they occur in more focused locations.

Activity centers and special corridors are also important to recognize when identifying important corridors for freight in the state. Military bases, border crossings, terminals or transfer stations (railroad or marine), factories, and warehouses are not always located in areas where there is a large concentration of population or employment. However, it is important to consider these activities when identifying freight corridors. Figure 15 illustrates the activity centers that were considered when identifying freight corridors in Texas. Additionally, specially designated corridors such as Ports-to-Plains, the Strategic Highway Network (STRAHNET) or the Strategic Rail Corridor Network (STRACNET) need consideration.

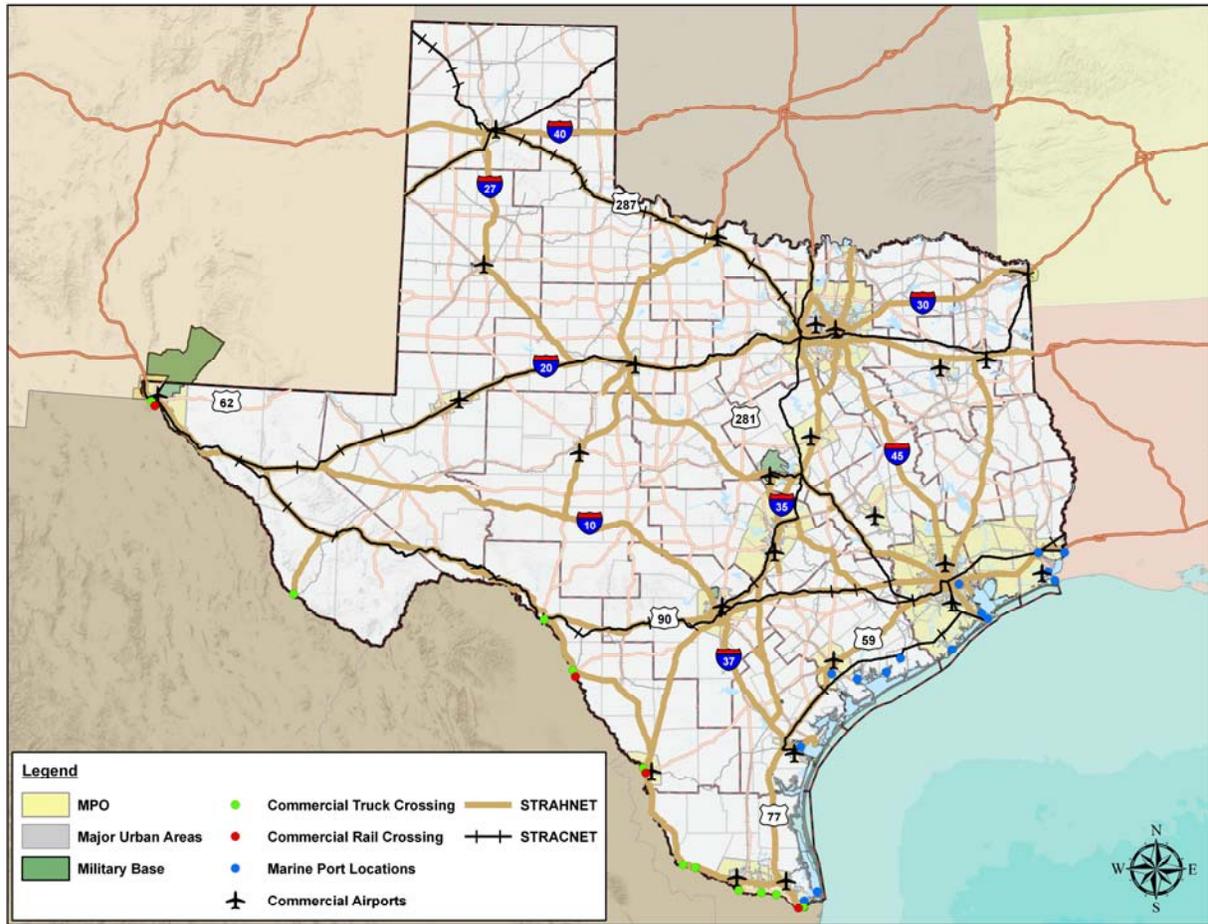


Figure 15. Freight Activity Center in Texas

Source: TranSystems.

In addition to population, employment, and activity centers, commodity flow data was analyzed to determine the existing volume of freight on roadways and rail lines in Texas. Figure 16 shows the total tonnage of commodities moving on Texas interstates and US and state highways. The line color represents the tonnage – a dark line represents a higher tonnage. The Texas interstate highway system carries the highest tonnage of commodities on the state’s highways. Several US and state highways on the east and north side of the state also carry significant volumes.

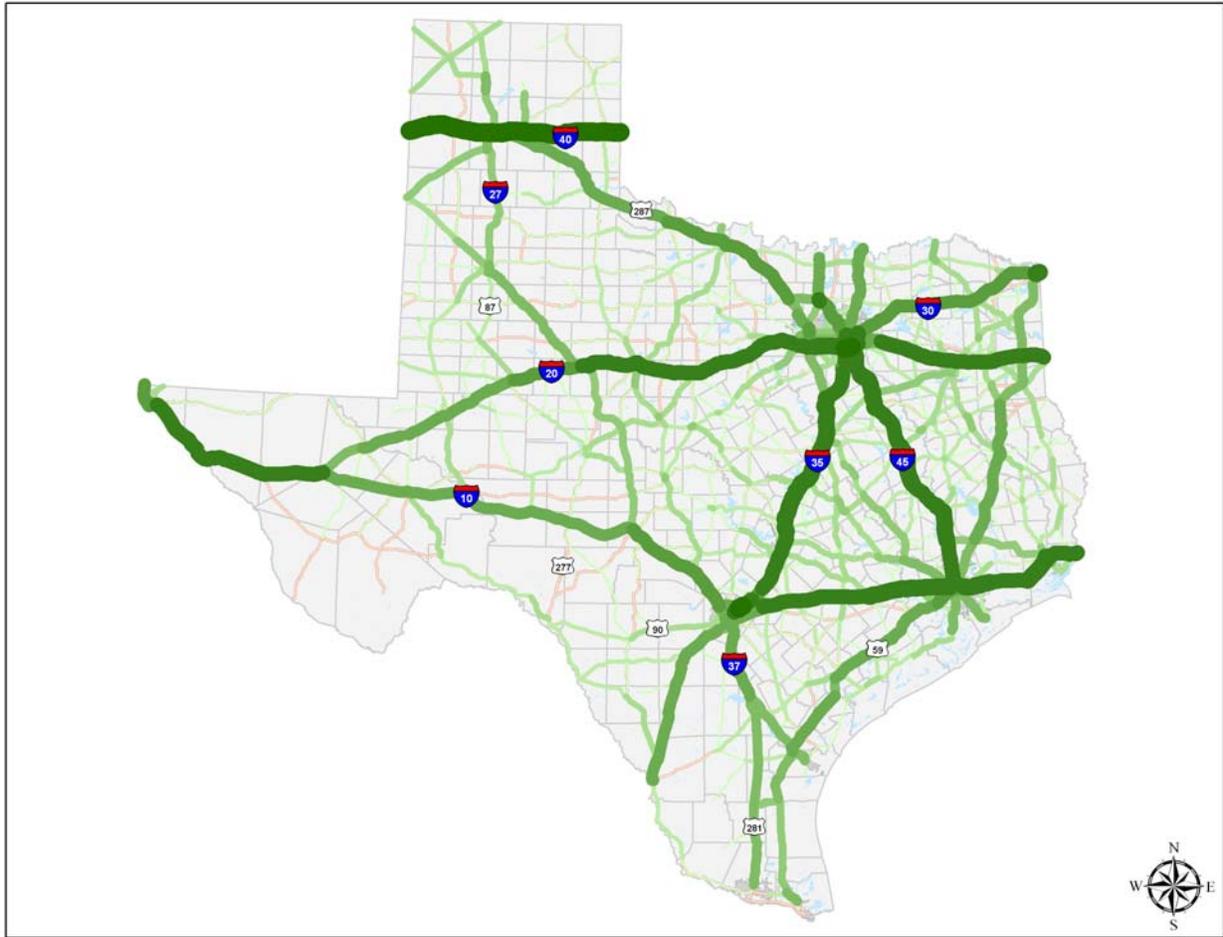


Figure 16. Relative Highway Freight Volumes (tonnage) in Texas

Source: TranSystems derived from 2003 TranSearch.

Figure 17 shows the total tonnage of commodities moving on Texas rail system. Again, the line thickness represents the tonnage – a dark line represents a higher tonnage. The Class I carriers in Texas (Union Pacific Railroad, BNSF Railway, and Kansas City Southern Railway Company) carry the highest tonnage of commodities in the state. Several shortline railroads provide vital connections to industrial and agriculture centers in Texas.

The heaviest travelled rail corridors in Texas occur along the Class I routes. Specifically on the BNSF, the transcontinental route across the Panhandle and the routes traveling between the Dallas-Fort Worth and Houston areas see high volumes of traffic. The Union Pacific corridors that parallel IH 10 and IH 20, as well as the routes leading in and out of Houston carry significant volumes. The KCS corridors going east from Dallas-Fort Worth and along the Gulf Coast are also important.

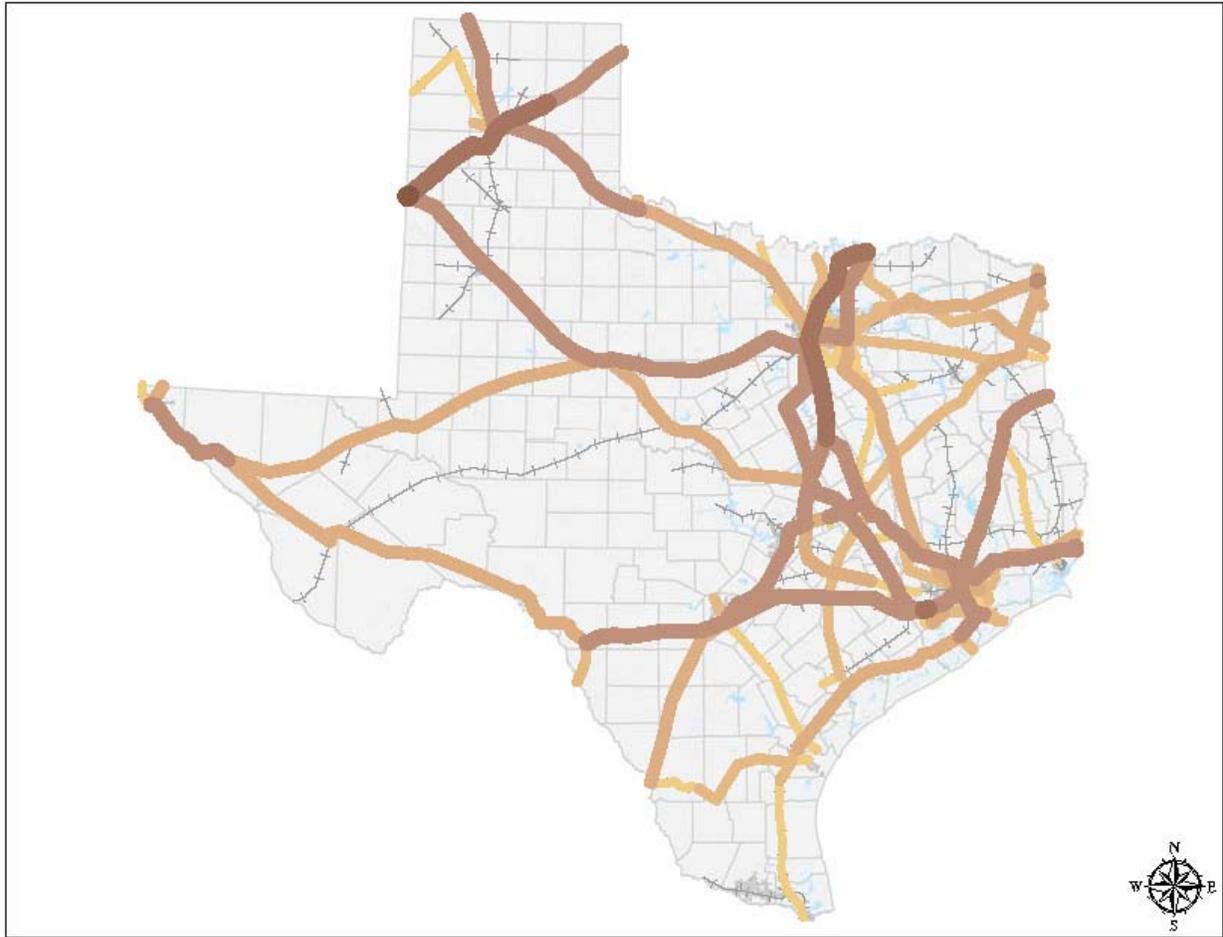


Figure 17. Relative Rail Freight Volumes (tonnage) in Texas

Source: TranSystems derived from 2003 TranSearch.

Using the maps created with Texas-specific data (population and employment density, activity centers, and commodity flows) corridors representing the strategic network for freight within the state of Texas were reviewed. Corridors connect major city pairs (i.e., El Paso to San Antonio to Houston) or travel through a centroid (i.e., Amarillo along the east-west highways and railroads). Within each corridor there are numerous highway and rail routes that will be the subject of more detailed assessments of resilience.

Hazard Identification and Assessment Methodology

Past damage to the Texas freight transportation system has occurred from natural and man-made hazards. It is important to identify hazards to determine the conditions, locations or events that could cause or contribute to unplanned or undesired circumstances. While this plan will identify and assess specific hazards, it is important to recognize that most response and recovery functions are not hazard specific. Therefore, planning should encompass all hazards and outline the basic response and recovery functions to execute whether the event is caused by nature or man-made hazards.

From 1953 to 2010, there were eighty-three federally-declared disasters in Texas due to floods, hurricanes/tropical storms, tornadoes, drought, and wildfire. The state's hazard mitigation plan considered these declarations along with other resources to address risks associated with fourteen natural hazards. (17) The SFR Plan referenced federal, state, and local resources to identify a subset of the fourteen state-level hazards in which the freight transportation system is most vulnerable. The following ten hazard types are identified as appropriate for this plan:

Table 2: Identified Hazard Types	
Earthquake	Tornado
Flood	Volcano
Hurricane	Wildfire
Landslide	Wind
Man-made	Winter Storm

Source: TranSystems.

The purpose of a hazard identification and assessment is to locate areas of vulnerability in each corridor to effectively understand how to eliminate or reduce risk associated with a hazard. Each hazard type was assessed based on the frequency of occurrence, warning time, and its potential severity directly related to impacts on the freight transportation system which may be different than impacts to other critical infrastructure, like housing or medical facilities. Data from the Texas Hazard Mitigation Package (an online digital geographic data resource for hazard analysis in Texas) was used to develop maps detailing the geographic location of areas vulnerable to each hazard identified. Much of the information on historic occurrences and mitigation actions was taken from the State of Texas Hazard Mitigation Plan (17).

Table 3: Hazard Impact Summary				
Hazard Type	Frequency of Occurrence	Warning Time	Potential Severity	Hazard Rating for Freight in Texas
Earthquake	Unlikely	None	Substantial	2
Flood	Highly Likely	Minimal	Substantial	3
Hurricane	Likely	Well in advance	Major	3
Landslide	Occasional	Minimal	Minor	2
Man-made	Occasional	Minimal	Major	3
Tornado	Likely	Advance	Major	1
Volcano	Unlikely	Well in advance	Minor	0

Wildfire	Occasional	Advance	Minor	1
Wind	Likely	Advance	Limited	1
Winter Storm	Occasional	Advance	Limited	1

Source: TranSystems.

Earthquakes, while infrequent, do occur in Texas. Historically, areas near El Paso, the Panhandle, northeast, and south-central Texas have experienced earthquakes which suggests future earthquakes are possible and may occur without warning. While the potential for a damaging earthquake in Texas is small, the severity of this type of hazard could make a substantial impact on the freight transportation system.

In the state of Texas, flooding is one of the most frequent and damaging natural hazards. Flooding can be associated with heavy seasonal rain events, hurricanes, tropical storms, and thunderstorms. Most flood events occur with a reasonable amount of warning, which can allow early actions that prevent severe impacts. This type of hazard can substantially impact the freight transportation system by undermining roadways and railroads, prohibiting navigation of channels, and destroying structures and their contents.

The coastal areas of Texas are vulnerable to hurricanes (and tropical storms). This hazard is characterized by high winds and heavy rainfall that can potentially cascade into other hazard types, like flooding and tornadoes. Hurricanes are a devastating natural disaster that can damage the physical freight transportation network (i.e., roadways, railroads, waterways) but also supporting utility and communication infrastructure, making the level of severity of this hazard major. The warning time for hurricanes is typically days or weeks in advance of landfall. This lead time can allow for better preparedness that may lessen the severity of the impacts.

The IH 35 corridor is the main area within Texas that is vulnerable to landslide activity due to the type of soil and moisture conditions located here. This type of hazard can cause damage to roads, railroads, and building structures. In Texas, the methods used for commercial building construction more commonly mitigate for this hazard but damage can occur if engineering solutions are not employed.

Most often man-made hazards refer to terrorist activity; however, the freight transportation system can be impacted by human error (i.e., transportation vehicle collisions with infrastructure) or human disruptions (i.e., worker strikes). The *Estimating Terrorism Risk* study by the RAND Center for Terrorism Risk Management Policy suggests that density-weighted population is a simple risk indicator that may be preferred for some purposes. (18) Therefore, the risk associated with this hazard was measured based on county population density per square mile as reported in the US Census. Man-made hazards can be wide ranging and, therefore, difficult to predict the frequency, warning time or severity.

Tornadoes that occur in the northern two-thirds of Texas are typically the result of cold frontal systems from the north and west. Tornadoes that occur in the southern, coastal areas are typically the result of tropical storms and hurricanes. This hazard occurs



annually and can result in major damage to roadways, railroads, and structures. While the actual path and development of a tornado is unpredictable, the conditions that form tornadoes can be forecasted to provide warning to users of the freight transportation system.

Interest in impacts associated with volcanic hazards surfaced during the April 2010 volcanic activity in Iceland that impacted European airspace. No volcanoes exist in Texas, but there is a remote possibility that ash clouds from volcanoes in New Mexico and Mexico could reach into Texas. This hazard was reviewed for its impact to freight but due to the lack of physical presence in Texas, it was not included in the assessment.

Wildfires in Texas typically occur in wildlands or the interface between rural and urban settings. Most often fueled by vegetation, these hazards are typically sparked by lighting or human error/intention (i.e., sparks from vehicles, cigarettes, campfires) making agriculture and forested areas of Texas most susceptible to this hazard. The main impact of wildland fires on the freight transportation system is roadway closure due to emergency operations, poor visibility or fire damage. Interface fires may impact structures but it is rare to have a freight-related structure in an environment where wildfires are prevalent.

Wind hazards are characterized by high wind with little accompanying precipitation. The Panhandle region of the state is most vulnerable to this hazard type due to the lack of natural wind breaks like trees or elevation barriers. This hazard's impact on the freight transportation system is very limited. Wind damage to vehicles or structures is possible but the warning time associated with a wind event likely will allow for protection measures that minimize damage.

Winter storms in Texas are characterized by low temperatures and accumulation of snow and ice. While the frequency of these storms is less often than states farther north, this hazard can cause damage to freight transportation infrastructure and other supporting infrastructure like utility and communication systems, as well as, delays when roadways and railroads are closed. The Panhandle and North Central Texas are the regions most vulnerable to winter storm hazards.

Figure 18 shows the areas of high, medium, and low risk for each hazard type identified in the SFR Plan. The vulnerability to each hazard increases in the darker shaded areas on each map.

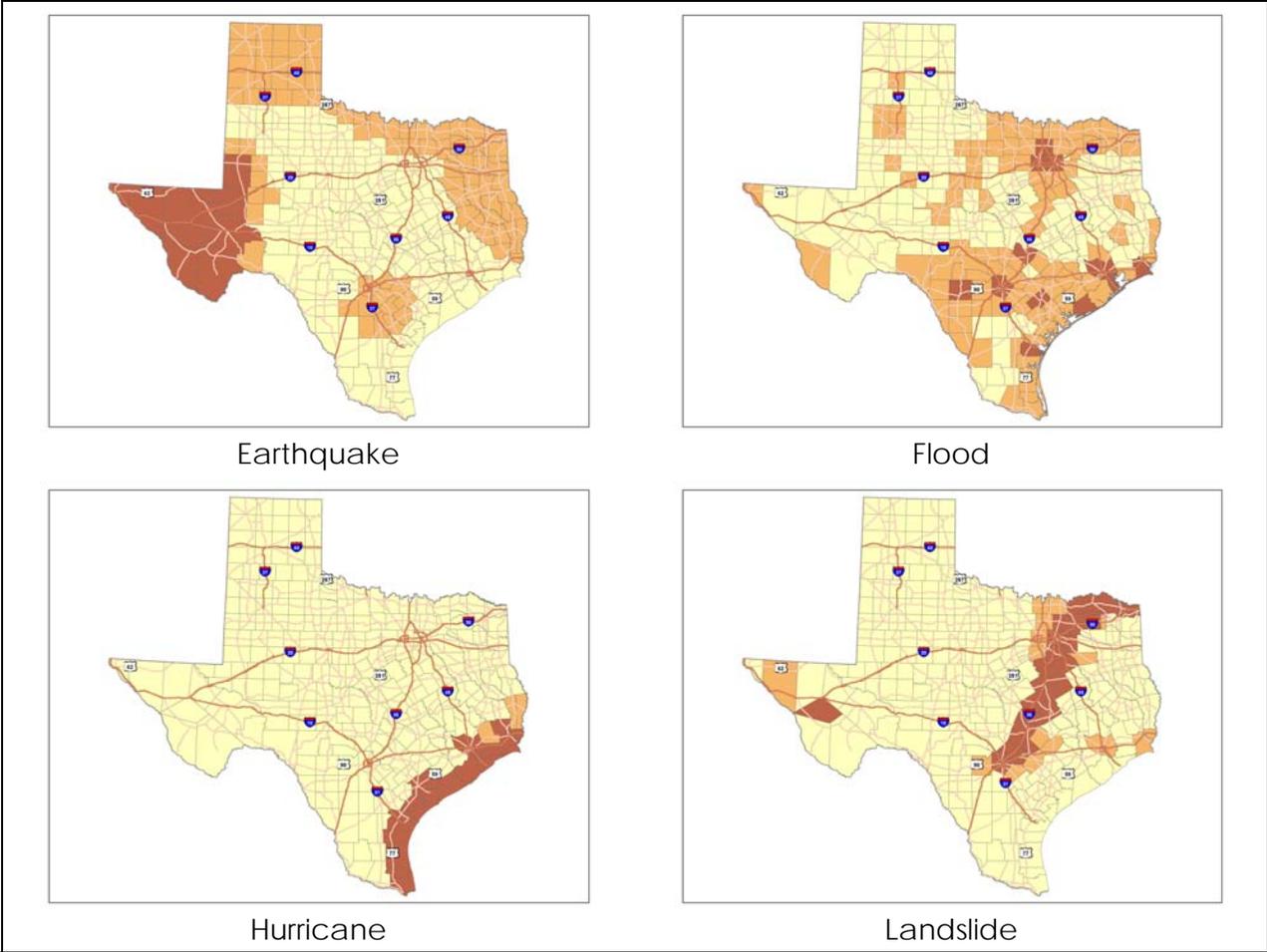
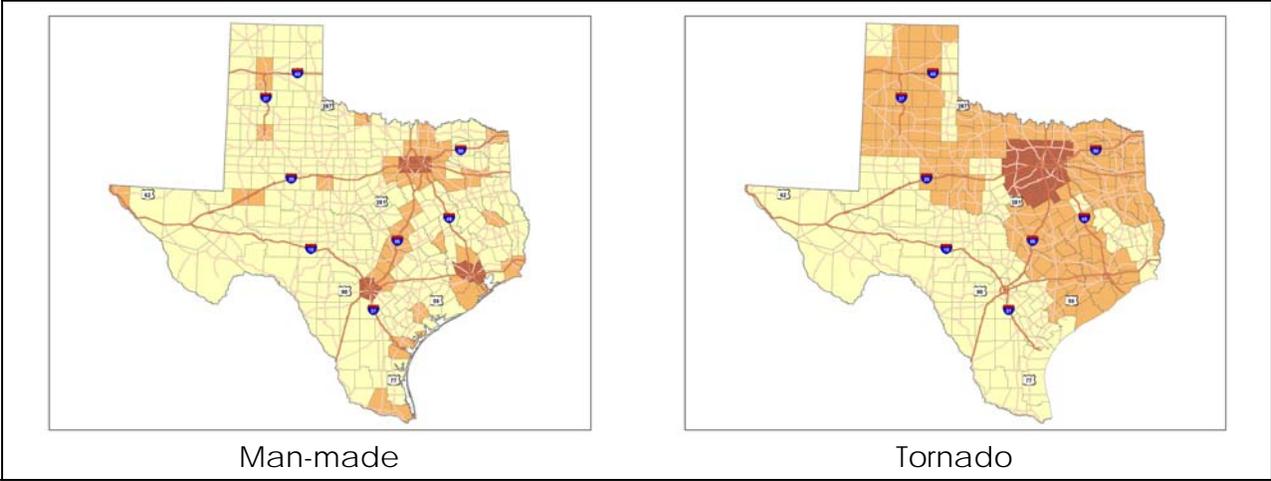


Figure 18. Hazard Locations in Texas
Source: TranSystems derived from Texas Hazard Mitigation Package and USGS.



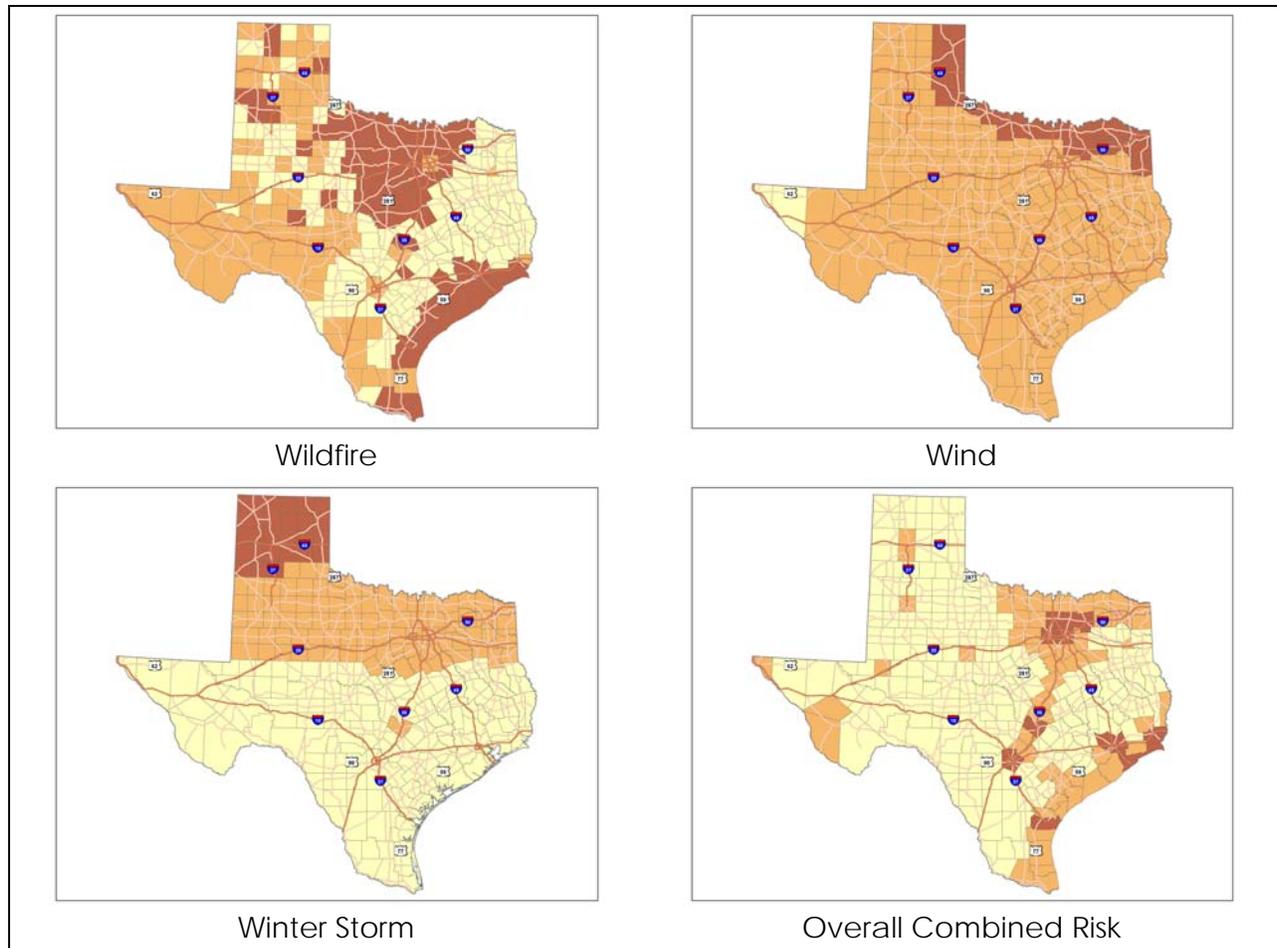


Figure 18 (continued). Hazard Locations in Texas

Source: TranSystems derived from Texas Hazard Mitigation Package and USGS.

The Overall Combined Risk represents the overall vulnerability of the freight transportation system to each of the hazards identified in Texas. The overall combined risk was developed by first combining all data for each hazard by county into one database. By hazard, each high risk county was given a value of 3, medium risk a 2, and low risk a 1. Each hazard was then weighted to better determine the overall risk hazard score for each county using the Hazard Rating shown in Table 3 (on Page 24). For each hazard, in each county a weighted risk was calculated and then combined to give an overall hazard risk value. After reviewing the range of values, the counties were then assigned high, medium, and low overall risk as illustrated in Figure 18.

The hazard risk assessment uses the results of the overall combined risk to evaluate all corridors. To assess each corridor, the individual hazard ratings for each county along the corridor are averaged by length of the corridor contained in that county. The resulting value for each hazard type is then average to provide an overall all-hazards corridor rating. These results are illustrated in Section 5.

Highway Assessment Methodology

The highway system assessment begins by assigning a primary, secondary, and connector highway route designation to the identified strategic freight corridors. A **primary highway route** is defined as the physical route representing a key freight corridor with statewide significance, connecting major activity nodes within Texas. A **secondary highway route** is defined as an alternate or redundant route to the primary highway route, providing access to the same major activity nodes during a resiliency event. A **connector highway route** is the highway link between the primary and secondary highway routes, allowing for segmentation and travel between the routes. The highway assessment focuses upon the physical and operational characteristics of the primary route to determine its robustness. Once robustness is measured, the assessment focuses on the physical and operational characteristics of the secondary route(s) to select a “preferred” redundant route in the case of an event.

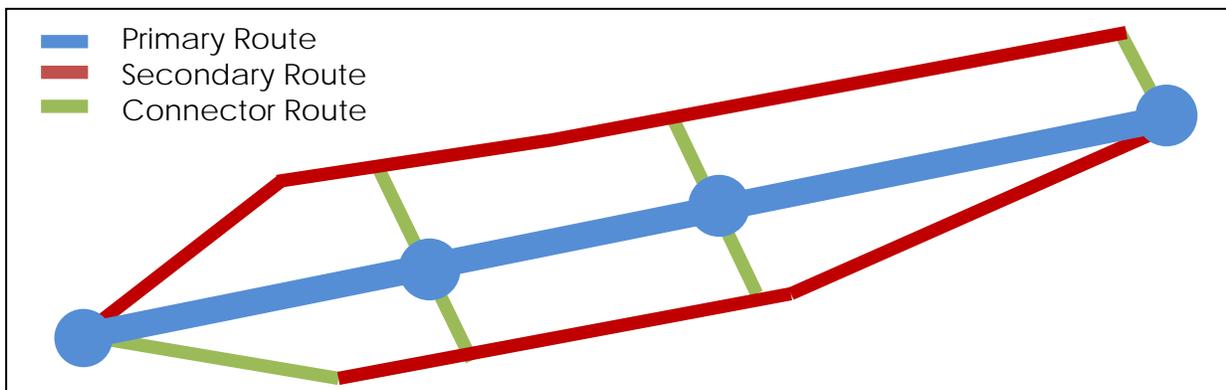


Figure 19. Illustration of Primary, Secondary and Connector Routes

Source: TranSystems.

Several key assumptions govern the highway assessment. First, a worst-case scenario is assumed in the corridor such that the disruption causes the entire length of the primary route to be out of service. Second, only one corridor at a time is out of service. Finally, the duration of the event is of sufficient length that a detour of truck traffic occurs.

For this assessment, while hypothetical, it is assumed that only truck traffic is allowed to detour to the redundant routes so that it is not overloaded with all diverted traffic. In this assessment, the existing general purpose traffic on the redundant route is allowed to continue at the same volume level as before an event and the rerouting of any truck traffic. While this situation would require a significant enforcement effort, it is deemed reasonable for the purpose of a resilience assessment.

Additionally, for this statewide plan the physical limits of the routes will stop at the major cities in the state. Most of the major population centers in Texas are designed with a circumferential highway network (e.g., IH 635 in Dallas). These “beltway” systems provide multiple redundant routes within cities but have their own set of physical and operational constraints due to existing travel conditions. Additionally, these cities are likely the origin or destination of the trips and commercial travel disperses within these



cities making it difficult to designate primary and secondary routes. For these reasons, the routes assessed in this study will not enter the urban areas.

The primary freight corridors typically traverse a significant portion, if not the entire length of the state, between two major activity nodes with other nodes along the corridors. The primary routes in Texas are the highest functional classification routes within the strategic freight corridors. These are mostly the interstate highways but some corridors are US routes. The secondary routes were selected based on their functional classification, proximity to the primary route, capacity for diverted truck traffic, and limited number of physical constraints. Two secondary routes, one on each side of the primary route, are designated for each primary route. Multiple redundant routes allow for more thorough review of physical and operating constraints, so that the best route is selected for use during a resiliency event. Connector highway routes link the primary and secondary routes. These segments mainly fall on state highways but at times follow lower classification routes. The connector highway routes are not assessed in this plan but are used to segment the primary and secondary routes.

In identifying specific secondary routes in Texas, several issues were identified.

- **Out of State:** A limited number of secondary routes cross out and back into Texas. While passenger vehicles may not notice a state boundary during their trips, this may complicate permitting for trucks and introduces a more complicated coordination effort if the route was used during an event.
- **Limited Secondary Routes:** Some primary routes have only one redundant route or no redundant route for a short distance. In this situation, the robustness of the primary route is the key concern and helps identify high priority segments of the primary route. Many times physical constraints like the Gulf of Mexico, the international border and state borders restrict options.
- **Duplicate Redundant Routes:** A limited number of secondary routes represent the redundant route for two primary corridors. While this is acceptable, it may result in constrained operations if multiple resiliency events occur at once.
- **Route Continuity:** A continuous route detour is much easier to sign by the DOT and easier to follow for typical drivers. However, this may make a detour route longer. In most cases, route continuity is maintained even though it may increase the overall trip distance.

The segments between the connecting routes are used to assemble the route characteristics. The segments typically measure between 50 and 100 miles in length. Route characteristic data is collected to assess robustness of the primary route and then the secondary routes. The data collected includes:

- Overall segment length
- Average Daily Traffic (ADT)
- Truck ADT
- Congestion measured by length of corridor exceeding volume to capacity ratio of 1.0

- Hazard Rating
- Vertical restrictions (less than 14' clearance), Lateral restrictions (posted locations), Weight restrictions (less than 40,000lb load)⁸

The primary route's robustness is assessed based on physical, operational, and hazard characteristics. A review of physical constraints is the first step of the assessment. Vertical, lateral, and weight restrictions may limit truck travel on certain roadways. A review of the Texas Motor Carrier Division Permit Maps provides information on these restrictions. Operational characteristics focus on roadway capacity based on the number of lanes available, speed, general purpose traffic volumes, and truck traffic volumes. General rules of thumb for vehicles per day are based on the Texas Statewide Analysis Model, with adjustments for event conditions. Hazard identification, like potential for flooding or exposure to weather-related events, is evaluated in terms of the severity or consequence of the hazard and the probability of occurrence of each type of hazard. The Texas Department of Public Safety provides worksheets to assess vulnerability and risk associated with various hazards.

To assess the robustness of the redundant routes (secondary route), a similar methodology is followed but truck volumes from the primary corridor are reassigned to the redundant route. This requires a more thorough assessment of the operational resilience of the secondary corridor's ability to accommodate the diverted truck volumes. Since the diversion of truck traffic is a result of a moderate to major event, a larger degree of tolerance for congestion is anticipated on the redundant route.

The willingness to tolerate the congested level may be a function of circumstances only discovered in the case of a specific event. However, severe congestion is considered a condition that demands attention to be improved to a tolerable level. In general, capacity issues arise when significant volumes of trucks are diverted to the redundant segments, some of which are only two-lane highways. When high truck volumes are diverted, many of the two-lane segments experience congestion. The assessment of the primary routes will consider the need for additional capacity for segments that experience congestion under normal conditions and for secondary routes that experience congestion during normal and event conditions. A cost for capacity improvements will be assigned by segment, allowing for a comparison between routes. A comparison of the secondary routes can determine which route is the better candidate for diversion based on the lowest cost to improve.

Physical characteristics focus upon potential limitations that could occur because of obstructions with vertical clearance at bridges, lateral clearance of truss bridges, and weight limit restrictions on bridges or other overhead structures. Temporary restrictions that may be associated with construction projects are not considered, although in the case of an actual event such information would be important to consider. Fortunately, from an overall perspective, the interstate and US highway network is typically not

⁸ These limits were set for this assessment and do not necessarily prohibit a standard load from traveling. This plan is assessing conditions to improve the preparedness of the highway system and borderline restrictions should be limited so that the system is more fully prepared.



limited by such obstructions. As is the case with operational characteristics, these physical characteristics can be fixed and an associated cost assigned to the improvement and used to compare routes.

The highway assessment looks at each corridor separately and after evaluating all corridors, a system assessment is summarized. A system assessment integrates the individual results of the corridor assessment to determine the level of statewide resilience for the highway transportation system. If there are few physical constraints and sufficient roadway capacity, the statewide highway transportation system can be considered resilient. If there are numerous physical and capacity needs, it is not resilient. A system-wide assessment helps to provide justification for the final step of the highway assessment, which is prioritization. Elements to consider for prioritizing the needs of individual corridors are:

- high truck traffic volumes associated with high hazard exposure,
- high value associated with overall economic impact,
- certain commodities associated with a specific industry's economic impact, or
- a combination of any or all of these factors.

Railroad Assessment Methodology

Railroads have extensive experience with addressing service disruptions within the course of providing every-day rail service. Responding to rail service disruptions caused by train derailments, weather-related events that damage tracks and bridges or long-term maintenance projects are a crucial component of maintaining reliable rail service. As such, resiliency planning is considered to be an integral component of daily operations. Public and railroad personnel safety are the key considerations both in every day operations and in freight resiliency planning. Railroads have a well-coordinated response to service interruptions because they are the managing organization(s) for the rail network.

The rail system assessment looks for ways that TxDOT can assist private rail operators and be prepared for potential mode shift associated with possible disruptions to the rail network. While TxDOT is the managing organization for the South Orient Rail Line, a state-owned facility that runs from Presidio on the Mexican border to San Angelo Junction, private rail companies are the managing organization for all other rail facilities in Texas. Due to share of ownership, it is more important to focus the assessment for rail resiliency in Texas on the ways that TxDOT can assist when resiliency events impact rail service.

A complete blockage of rail service in Texas is extremely unlikely. However, small areas could conceivably become inaccessible for extended periods of time due to severe track damage. The result would be increased truck traffic between the first available rail access point and points beyond the rail outage. Any mode shift to truck would put additional stress on the local transportation network surrounding terminals that may not be designed to handle the additional volume.



The rail system assessment will use a case study approach to determine ways TxDOT can assist and be prepared for events disrupting rail service in Texas. Case studies examine past events and the actions that railroads have taken to prepare, respond, and recover. From their actions and suggestions gathered during interviews, an assessment of the overall rail system resilience is conducted.

Assessment of Other Modes: Marine, Air, and Pipeline

Marine, air, and pipeline modes often have no close substitutes, especially in the short term, so a robust system is the best approach to resiliency for these modes. Resiliency plans for these modes focus on the safety of the public and personnel, along with implementing procedures that are designed to bring systems back on-line in a safe and effective manner.

As with rail resiliency, TxDOT must be aware of impacts that an event may have on other modes (marine, air, and pipeline), so that any cascading effects to the highway or coastal waterways can be adequately managed. Mode shift to trucks using the highway is an option during events that close or limit access to the marine ports in Texas, as well as airports and pipelines.

Similar to the rail system assessment, the assessment of other modes will use a case study approach to determine ways TxDOT can assist and be prepared for events disrupting cargo movement by other modes in Texas. Case studies examine past events and the actions that managing organizations have taken to prepare, respond, and recover. From their actions and suggestions gathered during interviews, an assessment of the overall modal system resilience is conducted.

Section 5. Assessing the Texas Freight System for Resilience

The results of the Texas Freight System assessment are presented for highways, railroads, and other modes. The highway assessment looks at each corridor separately and then after evaluating all corridors, a system assessment is summarized. A case study approach is used for the rail system and other modes to determine ways TxDOT can assist and be prepared for events disrupting these modes in Texas. This section of the plan focuses on the assessment results that measure the robustness and redundancy of the freight transportation system corridors and any potential constraints.

Highway Corridor Assessment Results

Ten primary corridors were identified for the Texas highway freight transportation system. Eight corridors were considered established freight corridors with significant volume of existing truck traffic. Two corridors, US 59/281 and the Ports-to-Plains corridor are classified as important, emerging corridors for highway traffic in Texas. Each of the primary corridors is illustrated on Figure 20.

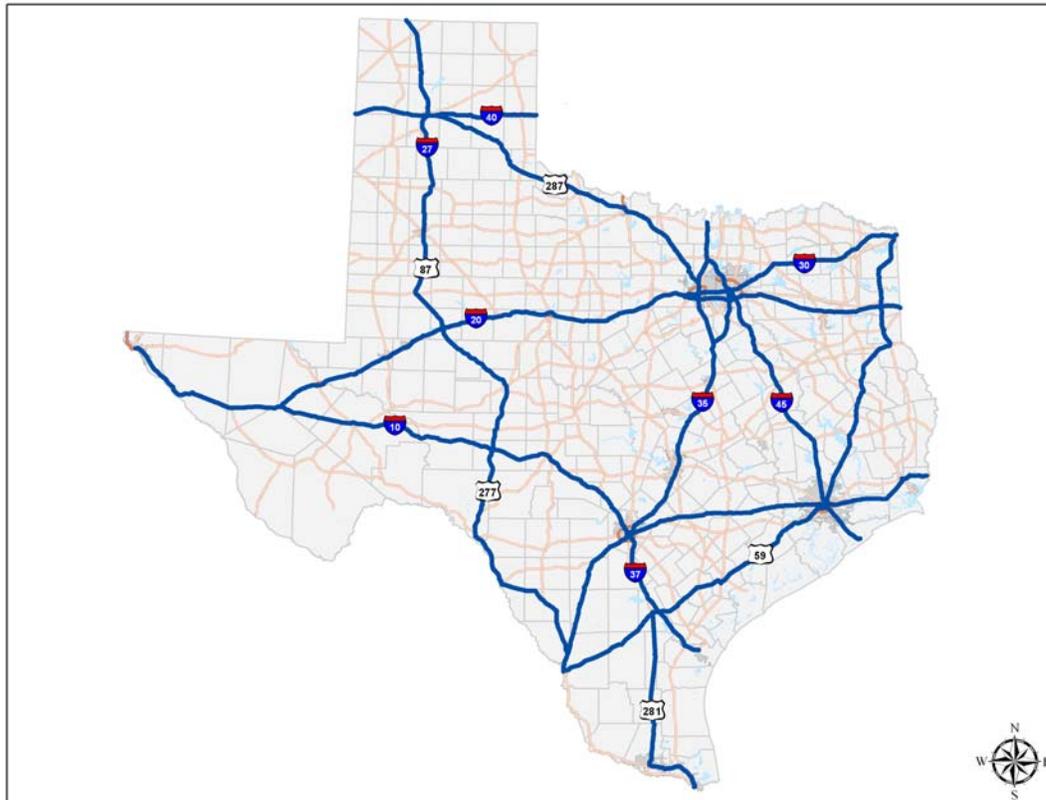


Figure 20. Primary Highway Routes in Texas

Source: TranSystems.

The following pages summarize the assessment of each Texas corridor. A general corridor description and map are provided along with summary data for the primary and secondary routes. Physical constraints are vertical, lateral, and weight restrictions. Operational constraints are a measure of capacity or stop-n-go traffic. Results for the



primary routes show existing travel conditions, so even a poor rating is tolerated; however, this does indicate a need for improvement. On the secondary routes, the result listed is for conditions when the primary route trucks have shifted to the secondary route. A chart illustrating the hazard ratings along the primary route is included. Finally, an assessment of the overall corridor is provided. Specific information on each corridor is discussed. For instance, many of the secondary routes are two-lane roads and during an extended duration event there is likely to be a great need for operational upgrades to these routes.

Interstate 10

Interstate 10 traverses the entire length of Texas from El Paso near the border with New Mexico to Beaumont near the border with Louisiana. This corridor connects major population nodes in the state: El Paso, San Antonio, and Houston. This corridor is one of the longest corridors assessed at 820 miles (excluding urban areas).

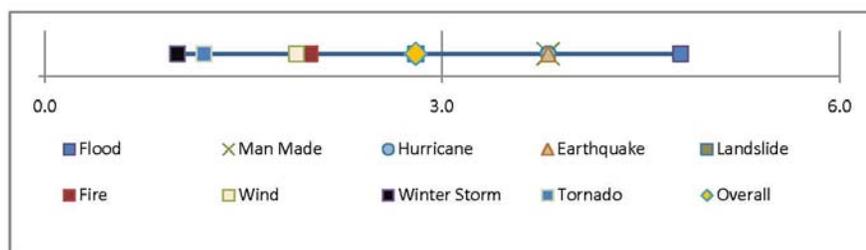
The north secondary route follows US 62, US 285, IH 20, US 67, US 87, US 290, IH 35, US 79, US 190, and SH 87- ten different routes. This route crosses into New Mexico on the western end. The south secondary route does not begin for approximately 100 miles east of El Paso and ends approximately 25 miles west of Louisiana. The western half of the south secondary route follows US 90. Between San Antonio and Beaumont the route follows US 87, Alt US 90, and US 90.



Daily truck volumes range from 2,000 per day near Fort Stockton to over 20,000 per day in the Houston area. Some of the major commodities carried on IH 10 include petroleum, chemicals, and consumer products.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
IH 10	820	7,200	2.8	1	Very Little
North Secondary	1,060	2,000	Lower	4	Some
South Secondary	680	900	Similar	6	Some

Corridor Hazard Risk by Type



Operationally, the robustness of IH 10 is very high between El Paso and Houston. At Houston and to the east, the route experiences higher levels of congestions. Over the 820 mile length, there is relatively little stop-n-go traffic. The south secondary route has a lateral constraint. The overall hazard rating for the corridor is a 2.8, which is relatively low; however, the corridor is more vulnerable to specific event types like flooding and to a lesser degree man-made, earthquake, and hurricane hazards. Both redundant, secondary routes have areas of operational constraints due to 2-lane segments with lower capacity than needed for the detour truck traffic.

Interstate 20

Interstate 20 reaches from West Texas to northeast Texas. Nodes along this route include Midland-Odessa, Abilene, and Dallas-Fort Worth. The western half of this corridor is located in undeveloped areas of Texas with long distance between cities.

The north secondary route follows SH 54, US 68, US 380, US 69, and US 80. This route crosses into New Mexico on the western end. The north and south secondary route begin on IH 10 about 50 miles west of the IH 10/IH 20 split. The south secondary route follows US 90, IH 10, US 67, US 84, and US 79. This route is nearly 400 miles longer than the primary route. The western portion of the corridor has fewer secondary route options.

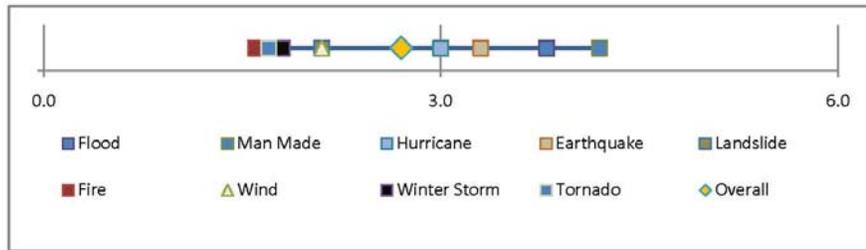
Daily truck volumes range from 4,000 per day



near the IH10/IH 20 split to over 11,000 per day near the Louisiana border. Some of the major commodities carried on IH 20 include petroleum, food, and lumber.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
IH 20	580	8,700	2.7	0	Very Little
North Secondary	770	1,200	Similar	3	Some
South Secondary	970	900	Lower	3	Very Little

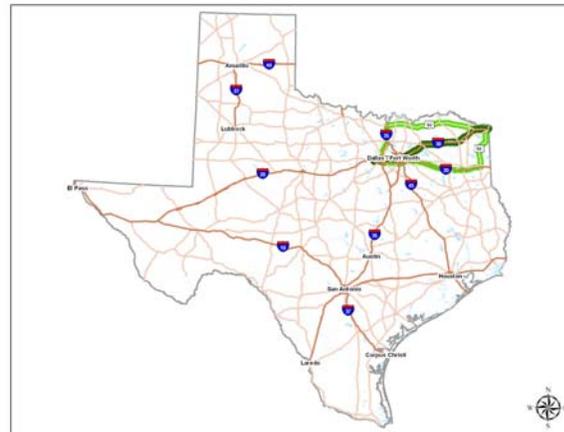
Corridor Hazard Risk by Type



Operationally, the robustness of IH 20 is very high over the entire length of the corridor. Over the 580 mile length there is relatively little stop-n-go traffic. Physical robustness of IH 20 is good with only vertical restrictions on its secondary routes. The overall hazard rating for the corridor is a 2.7, which is relatively low; however, the corridor is more vulnerable to specific event types like flooding and to a lesser degree landslide and earthquake hazards. The north secondary route has more areas of operational constraints due to 2-lane segments with lower capacity than needed for the detour truck traffic. The north secondary route also crosses into New Mexico, requiring more coordination if this route were used during an event.

Interstate 30

Interstate 30 is a relatively short, yet important corridor in Texas measuring 170 miles. This corridor connects Dallas-Fort Worth to the Ohio River Valley and farther on to New England states.



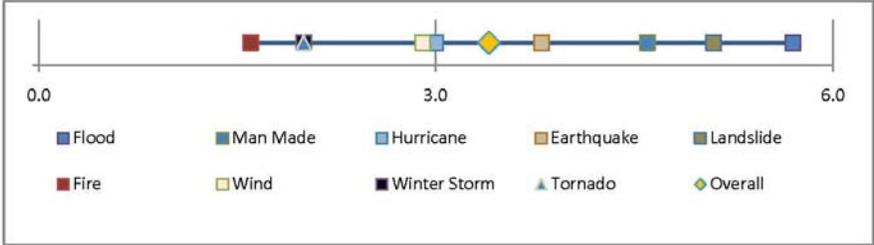
The north secondary route follows IH 35 and US 82. The south secondary route follows IH 20 and US 59. Daily truck volumes range from 6,000 to over 11,000 per day. Manufactured goods, food, and consumer products are some of the major commodities shipped on this corridor.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
IH 30	170	8,200	3.4	1	None
North Secondary	210	4,200	Similar	0	Majority



South Secondary	140	8,500	Lower	0	Very Little
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Corridor Hazard Risk by Type

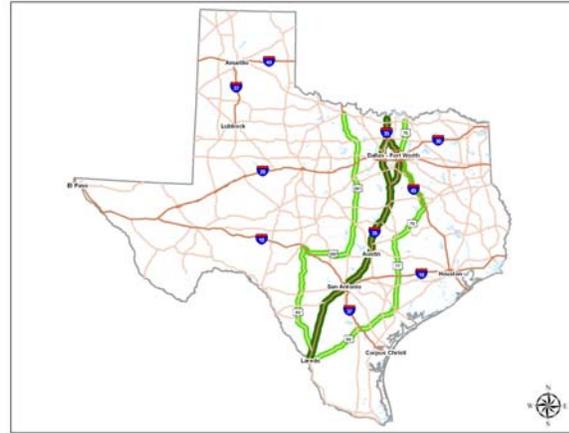


Although this corridor's relative distance in Texas is short, it carries a significant volume of truck traffic and at 3.4 has the highest overall hazard rating of all the corridors reviewed in the state. The highest individual hazard ratings are for flooding, landslides, and man-made events. While IH 30 itself has no operation constraints related to capacity, its north secondary route is constrained. Relocating truck traffic to the portion of the north secondary route along IH 35 would increase truck volumes to a level that would cause major stop-n-go traffic. Additionally, most of US82 is a two-lane route that cannot efficiently accommodate truck volumes that would be shifted from IH 30. Operationally, the south route is the better redundant route as it has more capacity along its length.

Interstate 35

Interstate 35 traverses the entire north-south length of Texas from Laredo near the border with Mexico to Gainesville near the border with Oklahoma. This corridor connects major population nodes in the state: San Antonio, Austin, and Dallas-Fort Worth. This corridor is important for the movement of international goods between the US and Mexico. IH 35 East through Dallas-Fort Worth was considered the primary route as it experiences slightly higher truck volumes than IH 35 West.

The west secondary route follows US 83, IH 10, US 290, and US 281. This route is nearly 1.5 times longer than the primary route and depending on the final destination would require additional mileage to connect back to IH 35 on the north end. The east secondary route follows US 59, US 77, US 79, IH 45, and US 75. This route also requires additional

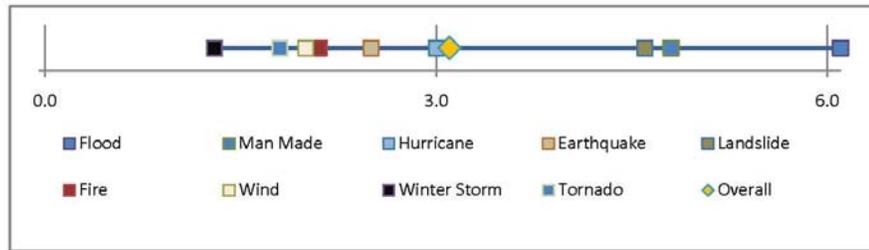


mileage to connect back to IH 35.

Daily truck volumes range from 4,000 per day north of Laredo to over 16,000 per day between Austin and Dallas-Fort Worth. Some of the major commodities carried on IH 35 include manufactured goods and consumer products.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
IH 35	440	10,600	3.1	7	About Half
West Secondary	640	800	Lower	1	About Half
East Secondary	580	3,100	Similar	1	About Half

Corridor Hazard Risk by Type



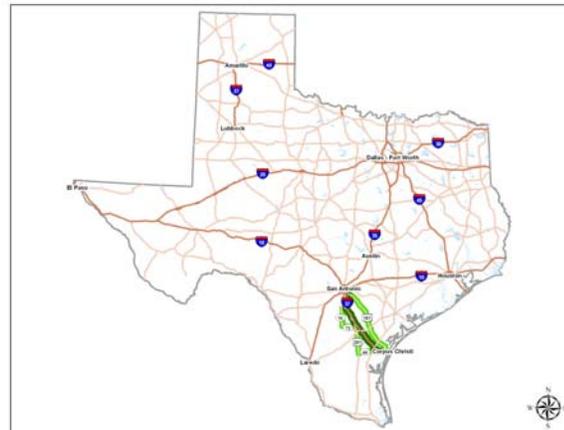
IH 35 and its secondary routes experience a relatively high level of congestion over the length of the corridor. Existing congestion is tolerated but could be improved. A resiliency event impacting IH 35 would strain the freight transportation system in the state. IH 35 is physically constrained by vertical restrictions between San Antonio and Dallas-Fort Worth limiting the robustness of the corridor. The overall hazard rating for the corridor is a 3.1 which is the second highest rating of all corridors. The corridor is most vulnerable to flooding.

Interstate 37

Interstate 37 connects Corpus Christi to San Antonio. This 130 mile corridor links one of Texas' maritime ports to a major population center and other connecting interstate highways.

The north secondary route follows US 181. The south secondary route follows SH 44, US 281, SH 72, and SH16. When selecting secondary corridors it was desired to stay on US highways; however, there are few US highway routes available within acceptable detour distances south of IH 37.

Daily truck volumes range from 3,000 per day to over 8,000 per day.

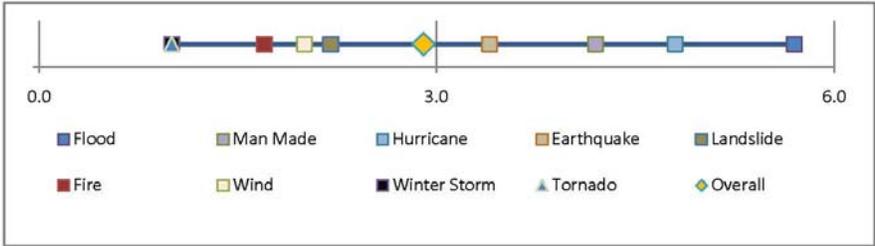


Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
IH 37	130	6,400	2.9	0	Some
North Secondary	170	1,300	Lower	0	None



South Secondary	140	600	Similar	0	Some
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Corridor Hazard Risk by Type



Operationally, the robustness of IH 37 is very high over the entire length of the corridor. Over the 130 mile length there is some stop-n-go traffic mainly concentrated at the two nodes – Corpus Christi and San Antonio. Physically, IH 37 is very robust as it only has one vertical restriction on its south secondary route. The overall hazard rating for the corridor is 2.9 which is relatively low; however, the corridor is more vulnerable to specific event types like flooding and hurricanes. The south secondary route has more areas of operational constraints due to 2-lane segments with lower capacity than needed for the detour truck traffic.

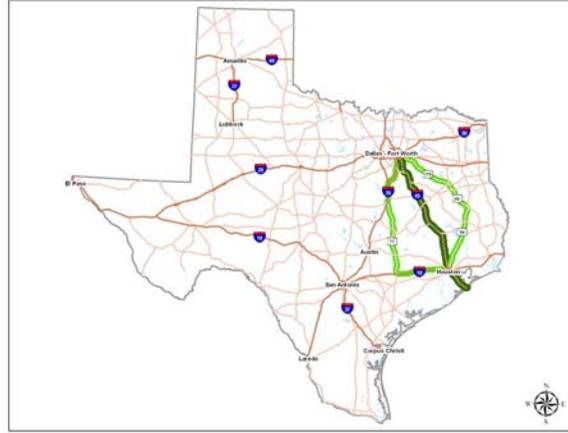


The robustness of IH 40 and its secondary routes is very high over the entire length of the corridor. Over the 180 mile length there is some stop-n-go traffic mainly concentrated around Amarillo. IH 40 has only vertical and weight physical constraints on its secondary routes. The overall hazard rating for the corridor is 2.7 which is relatively low however the corridor is more vulnerable to earthquake, man-made, and winter storm hazards.

Interstate 45

Interstate 45 connects the Houston area to Dallas-Fort Worth. This corridor serves one of the nation's largest marine ports and population centers. A portion of this corridor is located within the Houston metropolitan region and was not included in the analysis due to the multiple redundancies afforded by the highway network surrounding Houston.

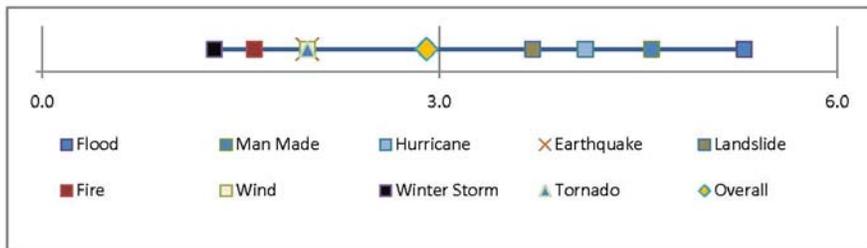
The west secondary route follows IH 10, US 77, and IH 35. This route is more than 1.5 times the length of the primary route. The east secondary route follows US 59, US 69, and US 175. This area of the state has multiple routes available to create significant redundancy for IH 45, beyond the routes designated in this plan.



Daily truck volumes range from 9,000 per day to over 12,000 per day. This is a major petroleum and chemical route in Texas.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
IH 45	220	10,800	2.9	1	Very Little
West Secondary	370	6,400	Similar	3	Some
East Secondary	270	4,300	Lower	5	Majority

Corridor Hazard Risk by Type





Operationally, IH 45 has very little stop-n-go traffic considering its high volume of truck traffic. Most congestion is centered near the major population centers. IH 45 has one location with a vertical constraint and one location on the east secondary route with a weight restriction. The overall hazard rating for the corridor is 2.9 which is relatively low; however, the corridor is more vulnerable to specific event types like flooding and man-made events. The east secondary route has more areas of operational constraints due to 2-lane segments with lower capacity than needed for the detour truck traffic.

US 287

US 287 follows the Oklahoma border from Fort Worth to Amarillo.

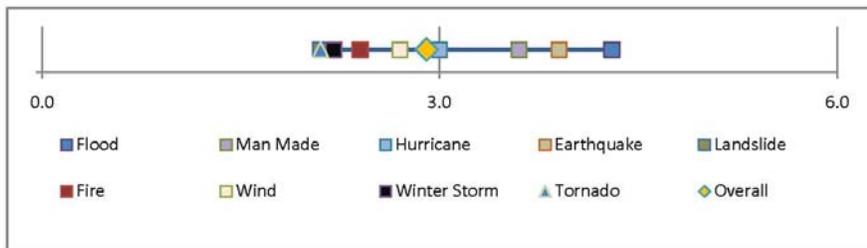
The south A secondary route follows IH 27, US 84, and IH 20. The south B secondary route follows IH 27, US 82, US 183/283, and US 180. There is no north secondary route as this corridor is directly adjacent to the state border with Oklahoma.

Daily truck volumes range from 2,500 per day near Amarillo to over 6,000 per day near Fort Worth. Some of the major commodities carried include food and petroleum.



Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
US 287	320	4,300	2.9	8	Very Little
South A Secondary	430	2,700	Similar	2	Very Little
South B Secondary	410	5,500	Lower	1	None

Corridor Hazard Risk by Type



Operationally, US 287 has very little stop-n-go traffic. US 287 physical constraints are mainly attributed to low vertical clearance on the primary route due to other roadways passing over US 287. The overall hazard rating for the corridor is 2.9, which is relatively low; however, the corridor is more vulnerable to specific event types like flooding and man-made events. The South A secondary route has more

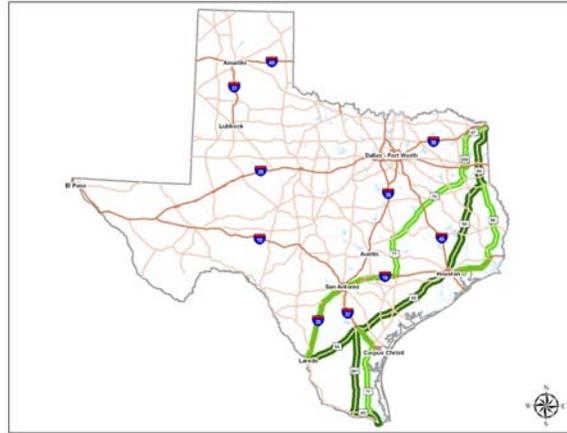


areas of operational constraints due to high truck volumes near Fort Worth on IH 20.

US 59

US 59 is a relatively long corridor in the state reaching from the Mexican border to Arkansas. US 59 starts in Laredo and travels north of Corpus Christi, through Houston on to Texarkana. A major portion of US 59 in Texas is a federally designated high priority corridor under consideration for upgrading to interstate standards with the designation IH 69.

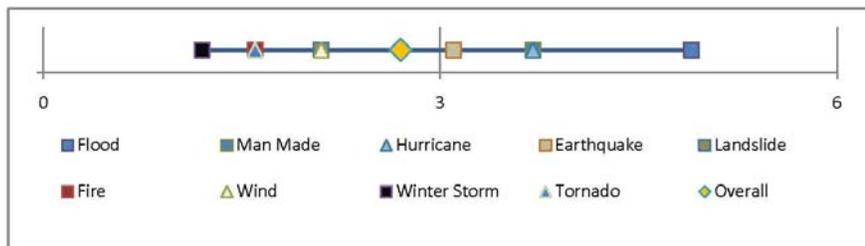
The west secondary route follows IH 35, IH 10, US 77, US 79, US 259, and US 67. US 59 follows the Texas Gulf coastline limiting the options for a secondary routes between IH 37 and Houston. Therefore, the east secondary routes starts at IH10 in Houston following US 96 back to US 59 near Tenaha.



Daily truck volumes range from 1,000 per day near Laredo to around 8,000 per day north of Houston.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
US 59	620	5,000	2.7	4	About Half
West Secondary	610	4,900	Lower	3	Some
East Secondary	220	12,600	Higher	1	Majority

Corridor Hazard Risk by Type



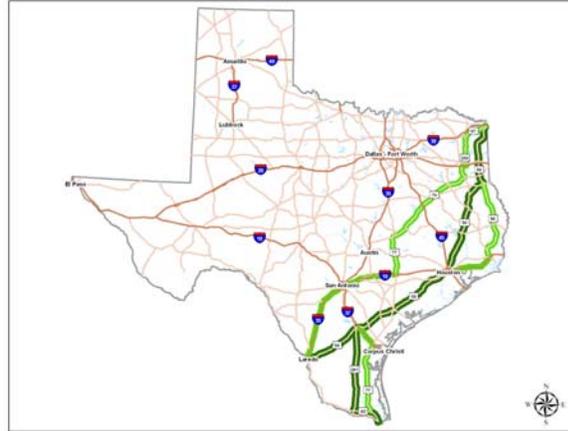


Segments of US 59 near Houston carry relatively high volume of truck traffic for the roadway capacity available. US 59 has six vertical restrictions all related to railroad overpasses. The overall hazard rating for the corridor is 2.7, which is relatively low; however, the corridor is more vulnerable to specific event types like flooding, man-made, and hurricane events. The east secondary route has more areas of operational constraints due to high truck volumes near Houston and Beaumont.

US 281

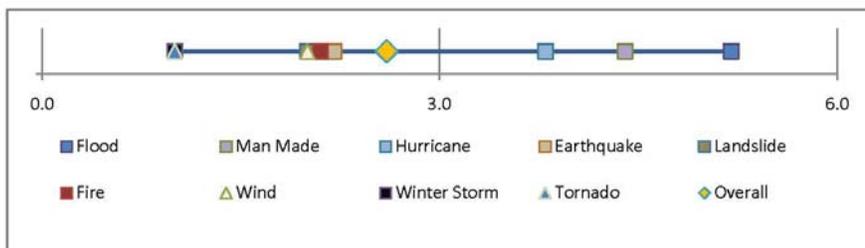
US 281 provides a connection for the southern most tip of Texas to other primary corridors in the state. This corridor connects McAllen and Brownsville to IH 37 north of Corpus Christi. This segment of US 281 is also considered an optional alignment for the future IH 69 corridor. The entire IH 69 corridor is depicted in the figure; the assessment show here focuses on US 281.

There is only an east secondary route because of the proximity of US 59 to the west. The east secondary route follows US 77 along the Texas Gulf coast. Daily truck volumes range from 1,000 per day near Laredo to around 8,000 per day north of Houston.



Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
US 281	210	5,400	2.6	0	Very Little
West Secondary	-	-	-	-	-
East Secondary	170	3,400	Higher	0	Very Little

Corridor Hazard Risk by Type





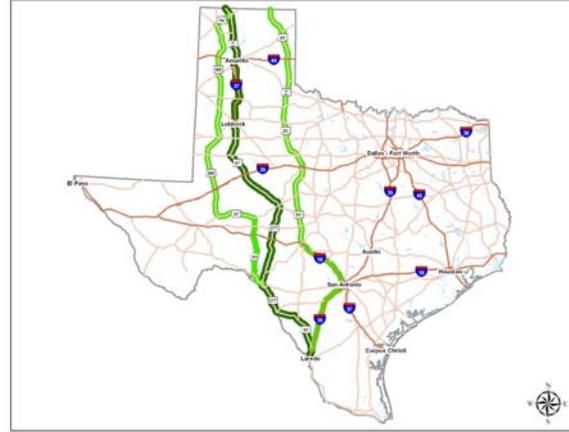
Segments of US 59 near Houston carry relatively high volume of truck traffic for the roadway capacity available. US 281 has no physical constraints. The overall hazard rating for the corridor is 2.7, which is relatively low; however, the corridor is more vulnerable to specific event types like flooding, man-made, and hurricane events. The east secondary route has more areas of operational constraints due to high truck volumes near Houston and Beaumont.

Ports-to-Plains

Ports-to-Plains is the longest primary corridor assessed in the plan and it follows US 287, US 87, and IH 27 from Laredo north to the Panhandle. The Ports-to-Plains corridor is a federally designated high priority corridor on the National Highway System.

The west secondary route starts at Del Rio because much of the southern portion of the primary corridor parallels the border with Mexico. The west secondary route follows SH 163, US 67, US 385, and US 54. The east secondary route follows IH 35, IH 10, and US 83.

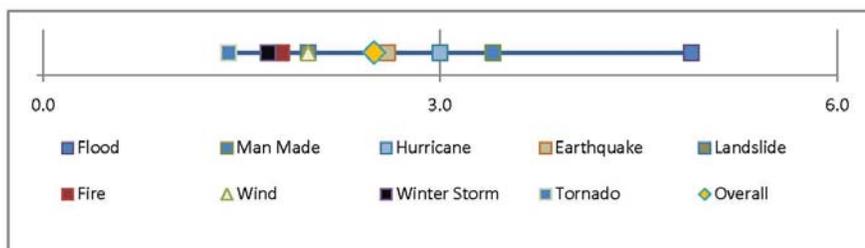
Daily truck volumes range from less than 500 per day on the southern end to 1,000 to 2,500 per day at the northern end.



Some of the major commodities carried on Ports-to-Plains include petroleum and agriculture.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
Ports-to-Plains	860	2,000	2.5	1	Some
West Secondary	600	1,000	Lower	1	None
East Secondary	690	1,800	Higher	2	None

Corridor Hazard Risk by Type





The Ports-to-Plains corridor only experiences operational constraints near Amarillo as traffic volumes increase. There are some two-lane roadway segments that constrain operations. The primary corridor and both secondary corridors have one location with a load restriction. There is a truss bridge in Val Verde county on the west secondary route that has lateral restrictions. The overall hazard rating for the corridor is 2.5, which is very low; however, the corridor is more vulnerable to specific event types like flooding and man-made events.

Overall Statewide Highway System Assessment and Prioritization

Resilience is really measured by four components: robustness, redundancy, resourcefulness, and rapidity. The Stage 1 SFR Plan focuses on preparedness of the freight transportation systems, which is measured by robustness and redundancy. The overall highway system assessment for preparedness concludes that the Texas highway corridors are highly resilient when considering robustness and redundancy. This is evidenced by the low overall hazard risk ratings, relatively few physical constraints and limited areas of operational constraints on the primary and secondary routes, as shown by the results in Table 4.

Route	Mileage	Daily Weighted Truck Volume	Overall Hazard Rating	Number of Physical Constraints	Length of Corridor Stop & Go
Statewide					
Primary	4,550	2,000 to 10,800	2.8	23	Some
Secondary	9,650	1,000 to 12,600	Similar	38	Some

Source: TranSystems.

While the assessment of preparedness for the statewide highway system is positive, there is still a need to continually improve the system. One way to prioritize the corridors for future investments to increase their robustness and redundancy is to review the overall hazard risk versus truck volume exposure.

Displaying the corridors in a hazard risk versus truck volume exposure matrix allows for a visual measure of the threat level experienced in a corridor. A risk vs. exposure matrix is used to prioritize based on where the data point falls in the matrix. For instance, it is undesirable to be in a high hazard, high exposure situation (upper right corner on Figure 21) and data points falling in this area may receive the highest priority. Data points that fall in the lower left corner are low hazard, low exposure and may not have as critical needs related to freight resiliency.

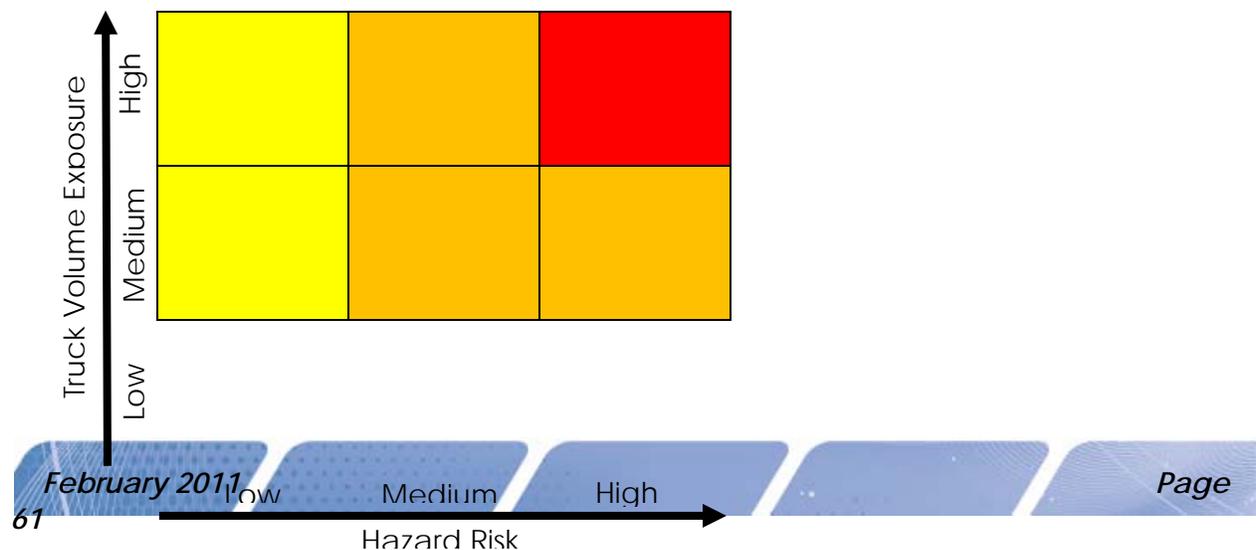




Figure 21. Risk vs. Exposure Matrix

Source: TranSystems.

Figure 22 plots all of the significant corridors' truck volumes against their overall and specific hazard type risks. Plotting the corridors in this manner allows a further assessment of their relative risk to prioritize planning for preparedness, response, and recovery in the various corridors.

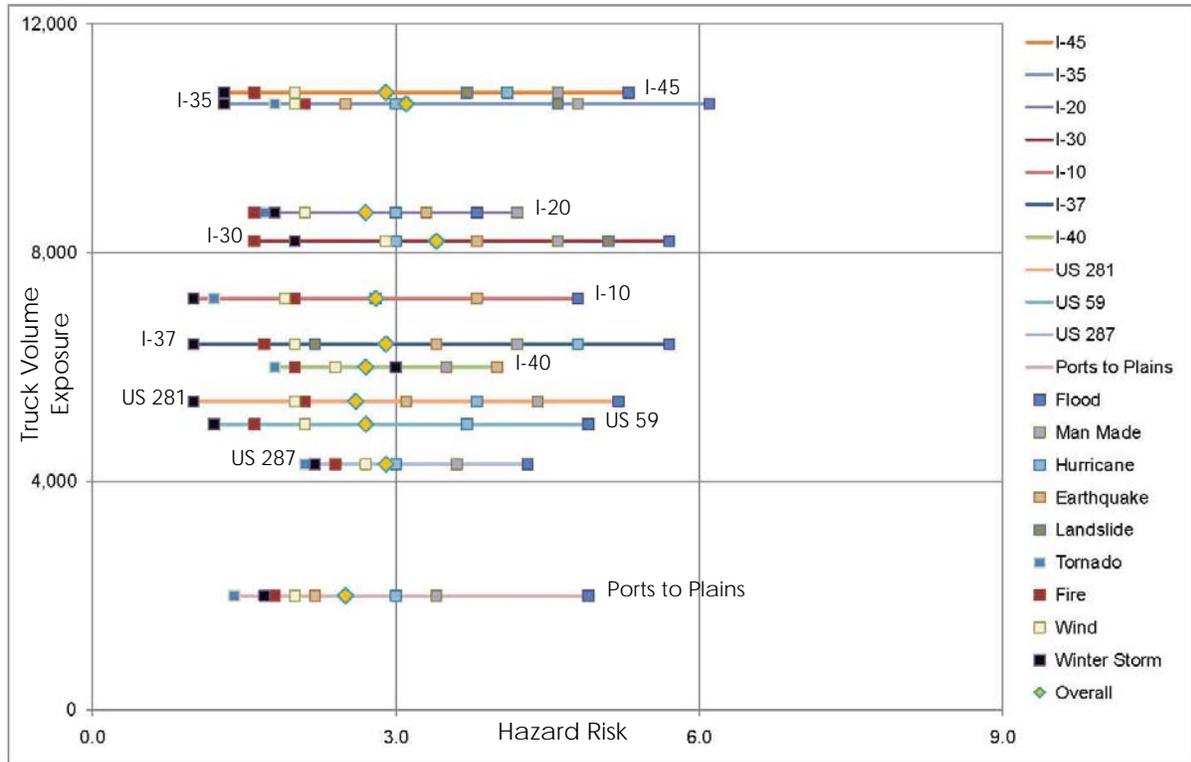


Figure 22. Texas Statewide Highway Corridors Risk vs. Exposure

Source: TranSystems.

Specifically for the Texas corridors, this graph plots a horizontal line to represent the adjusted average number of trucks traveling along the entire corridor. The data points along the line represent the hazard ratings for each hazard type and an overall hazard rating for the corridor. Using IH 30 as an example, the truck volume over the entire corridor is 8,200. Some segments of this corridor have higher volumes, others are lower. The overall hazard rating is 3.4. The hazard ratings range from 1.6 for wildfire to 5.7 for flood. The overall rating for this corridor falls in the high exposure, medium risk category.



Four highway corridors in Texas fall in the high exposure category: IH 45, IH 35, IH 20, and IH 30. No corridors fall in the high risk category. Two corridors fall in the medium risk category: IH 35 and IH 30. Other corridors fall in the upper end of the low risk category.

Using the risk vs. exposure plot, it appears that IH 35 and IH 30 should receive high priority for corridor improvements, as they have the highest risk and exposure combination of all Texas highway corridors (high exposure, medium risk).

Railroad Case Study Results

As private, profit-driven companies, railroads depend on reliable service to attract and retain customers. To ensure service for their customers, planning to eliminate or minimize service disruptions is considered to be an integral component of daily operations.

A railroad's approach to an event depends on the amount of preparation time that is available. A hurricane, for example typically provides enough lead time to institute a system shut down that involves the removal of rail assets, such as rail cars and locomotives, from areas that are expected to experience damage. Additionally, personnel and supplies needed to bring the rail system back online are prepositioned to ensure a rapid recovery. Generators are included in the prepositioning process to power rail communications systems, signals, and warning devices at highway-rail at-grade crossings in case of a power outage. Flag-men are posted at highway-rail at-grade crossings where power remains unavailable.

After the disruption occurs, railroads move to recovery. Tracks, bridges, and at-grade highway-rail crossings are inspected to confirm that safe operations can resume. If track repair is necessary, priority is given to tracks that can be repaired quickly. Long-term network outages are then handled by rail operations to identify new service routes.

Rerouting decisions depend on the length of the outage. Trains may be held in place if a disruption lasts for a day or two because the time to detour the train could equal the duration of the disruption. Rail outages of longer than a few days will require trains to be rerouted. Once the source of the outage is identified, a process is initiated that traces the network backwards until a passable route is established. The scope and severity of an outage dictates the backtrack distance needed to reroute the train. Trains that have the clearest and easiest path to their final destinations are rerouted first, and others that are most negatively affected by an outage, either by a severed connection or that require extensive rerouting are moved last. This methodology clears congestion as quickly as possible. During long rail outages, conversion to truck traffic may occur. Any mode shift to truck would put additional stress on the local transportation network surrounding terminals that may not be designed to handle the additional load.

Many times hazards that disrupt the railroad system will also disrupt the highway network. During these periods, TxDOT may also be managing repairs to its assets but TxDOT's assistance to private rail operators and preparations for potential mode shift should be considered during events. The following case studies illustrate the railroad's

approach to events followed by a summary of actions that TxDOT may consider to support railroad resiliency planning and recovery.

Hurricane Ike Rail Operations

Hurricane Ike, a Category 2 hurricane, made landfall on September 13, 2008 at Galveston, Texas. The damage inflicted by the hurricane was substantial and widespread. In anticipation of the storm, the BNSF closed their operations in Houston and Galveston on September 11 due to emergency preparedness activities. All rail traffic destined for the Houston and Galveston area was temporarily staged at origin and en route locations to ensure safe conditions. Initial delays were estimated at 48-72 hours.

On September 19, the BNSF reported that all track damaged by Hurricane Ike was open and available, except the track serving Galveston Island. The BNSF operates over the rail causeway owned by Galveston County that runs parallel to the IH 45 causeway. The causeway connecting the mainland to Galveston Island was flooded in advance of the storm due to the storm surge.

During this time, the Port of Galveston was closed due to significant damage caused by the hurricane. Therefore, the BNSF was able to prioritize track repair based on the demand, or lack of demand for rail service caused by port closure. The timing of repairs to track needed to access the port was delayed to coincide with the resumption of port operations that required rail service. In addition, railcars were positioned to alternative ports to handle cargo that was scheduled to be handled at Galveston.



Figure 23. Hurricane Ike Damage to Causeway

Source: David Frank, Bridge Administrator, Eight Coast Guard District. *Galveston Causeway Bridge*, Presentation at the 2009 Texas Ports and Waterways Conference. August 14, 2009.



On September 26, less than two weeks after the hurricane, the BNSF reported that repairs to the causeway were completed and the first train to the island arrived that morning. Not all customers in the areas impacted by the hurricane were able to accept rail service due to power outages and facility damage. However, BNSF instituted a permit embargo system for these shipments to maintain fluidity of their system. (28)

Landslide Requires use of Track Rights

Railroads have reciprocating track rights agreements that allow carriers to operate on tracks they do not own in certain corridors. These agreements may be permanent but can be negotiated on an as needed basis. The Union Pacific recently experienced a landslide that closed a portion of its tracks for 90 days. The BNSF allowed the UP to use its line while the UP section was repaired.

El Paso Flood Mandatory Evacuation

In the last days of July 2006, El Paso received nearly twice its annual average rainfall. The excessive rainfall caused flash floods, mudslides, and other damage to infrastructure. Concern over the stability of an earthen dam in Ciudad Juarez, Mexico caused the US Army Corps of Engineers to issue a mandatory evacuation of downtown El Paso on the evening of August 3, 2006. The evacuation order included the BNSF and UP rail yards in El Paso.

For several days preceding the evacuation, the railroads issued communications to their customers reporting delays of 24-36 hours due to track wash outs and other damage caused by the excessive rainfall. Interviewees reported that the rail yards were immediately cleared of all equipment and locomotives as the evacuation order was issued. While the earthen dam was stabilized and the evacuation order lifted, the recovery from the rain events continued for several days. The BNSF reported that its intermodal facility and train yard returned to service immediately after the evacuation order was lifted but some loads were held at origin over the weekend until normal service routes were back online. (29, 30, 31)

Overall Rail System Assessment

This general assessment of the overall rail system concludes that it is highly resilient out of necessity. Railroads cannot let damage to their system impact their operations for extended periods or they will lose customers. They employ many methods during resiliency events including preparedness functions and recovery. To prepare, railroads evacuate equipment and personnel while prepositioning materials, supplies, and equipment needed for repairs. During recovery they may utilize rerouting on their own system or on another carrier through track right agreements, while emergency repairs are conducted. In some cases, these agreements allow for a redundant rail network capable of responding to disruptions of virtually any duration.

While the railroads interviewed as part of this plan welcomed appropriate levels of assistance from TxDOT, their main request was assistance with overall emergency management coordination. Railroads rely on electricity to ensure safety, as well as to operate communication, signal, and highway-rail at-grade crossing systems. As part of emergency coordination, railroads requested that utility companies be made aware of



this need and consider giving railroad companies priority when maintaining and restoring power. Additionally, communication with law enforcement was noted as important during recovery functions in order to allow emergency rail crews to access tracks when public roads are closed.

Other Mode Assessment Results: Marine, Air, Pipeline

The diversity of freight in Texas requires that TxDOT consider supporting resiliency planning for all modes. The following case studies illustrate marine, air, and pipeline approaches to events followed by a summary of actions that TxDOT may consider to support other mode resiliency planning and recovery.

Pipeline: Safe Operation

In the US, over 2.5 million miles of pipelines deliver trillions of cubic feet of natural gas and hundreds of billions of ton/miles of liquid petroleum each year. This volume equates to 750 tanker trucks per day or one 75-tank car train per day everyday for a modest size pipeline. Understanding how a natural or man-made hazard may impact pipeline operations is important to TxDOT, because alternative transport by truck would cause congestion and other impacts, including pollution and potentially dangerous movements. (32)

The Pipeline and Hazardous Material Safety Administration's Pipeline Safety Program reported 59 significant pipeline incidents in Texas in 2009. These significant incidents resulted in one fatality, six injuries and \$34 million in public and private property damage. Pipeline companies spilled over 20,000 barrels and lost over 12,000 barrels of product. (33)

It is the pipeline operator's responsibility to ensure the safety and security of its pipelines. Federal and state regulations and industry standards ensure safe operation of pipelines. As with any private industry, pipeline companies must maintain their system at a level that provides the service their customers demand. Pipeline operators and regulators are constantly looking at ways to prevent events that may disrupt pipeline service and cause injury, death, and damage to property, as well as service outages. Efforts include research into damage prevention and leak detection technologies, enhanced operations, controls, monitoring, and improved material performance.

Air: Icelandic Volcano Eruption

On April 14, 2010 a second and stronger eruption of Iceland's Eyjafjallajokull volcano sent a plume of volcanic ash approximately seven miles into the atmosphere. Wind currents then blew the ash toward Europe sparking a shutdown of airspace as volcanic ash can cause significant damage to jet engines. For the next five days, European officials closed most airports requiring the cancellation of more than 100,000 flights. By April 21, European airports were reopened but normal conditions would not return for weeks. (34)

This event not only stranded travelers but halted air cargo operations requiring carriers to implement contingency plans to complete package deliveries. Perishable and high-value goods dependant on air freight were severely impacted by the grounding of



airplanes. Reports were made that Kenyan farmers were forced to dump stocks of fresh food and flowers destined for European markets. (35) According to the New York Times, a Dutch logistics company shifted air freight to the road network requiring it to hire additional trucks to complete customer deliveries. (36) UPS reported that it rerouted packages to Istanbul, Turkey and trucked freight to its final destination adding three days to their delivery schedule. (37)

Just-in-time manufacturers, food, and pharmaceutical companies are likely the largest users of air cargo services and were hardest hit by the European air cargo shutdown. This incident did cause some increase transit cost and minor short-term shortages. It also illustrated the need for flexibility and preparation by managing organizations, like TxDOT, who will see an increase in truck freight on its system in the case of a similar event in Texas.

Maritime: Hurricane Ike Port Operations

The damage inflicted by Hurricane Ike at the Port of Galveston was substantial and widespread. The Port's contingency plans were fully activated in advance of the storm to prepare for landfall and recover after the storm. Extensive water damage to port assets and infrastructure were reported including damage to port equipment, buildings, and terminals. Limited cargo operations resumed on September 22, 2008 with full operations resuming on October 6.

The Port of Galveston specifically reported that assistance provided by TxDOT led to their ability to receive and process roll-on roll-off and project cargoes. TxDOT personnel expedited inspection of the highway system connecting the Port to the Houston area. Permits for oversized cargo were also expedited by TxDOT allowing permit loads to move as early as September 26.

Maritime: Port of Houston Fog Closures

In December 2007, fog severely disrupted ship traffic over seven days at the Port of Houston, resulting in a period of intermittent port closures. Fog is common for the Houston area in the months of December and January; however, this fog event caused substantially more port closures than was usual causing port operators and ocean carriers to consider alternative operating plans.

The Houston ship channel is maintained at a depth of 45 feet, and a width of 530 feet. It is not uncommon for ships with a beam (width) of 150 feet or more to pass in opposite directions, leaving a margin of 230 feet to navigate between the channel edge and oncoming vessels. Figure 24 illustrates two vessels passing, each with a beam of 131 feet. Even under fair conditions, a high degree of navigational skill is required to transit the Houston Ship Channel. Figure 25 illustrates hazardous conditions caused by fog in the Houston Ship Channel.

Truck traffic resulting from container vessels uses the public road infrastructure surrounding the port. The main access to the Barbours Cut and Bayport container terminals, which are the area's key container terminals, include SH 146 and SH 225. Vessel movement data from the Greater Houston Port Bureau and traffic drive time

data from Houston TranStar were used to measure traffic conditions in an effort to understand how managing organizations for roadways (i.e., TxDOT) are impacted by a port disruption.



Figure 24. Containerships Passing in the Port of Houston Ship Channel

Photo used by permission: "Before", Lou Vest, Houston Pilots Association, September 2006.



Figure 25. Tankers in the Houston Ship Channel in Fog

Photo used by permission: "Fog in Tight Places", Lou Vest, Houston Pilots Association, March 2007.

To assess the impact of altered vessel arrivals on traffic patterns, traffic speed data provided by Houston TranStar, was correlated with vessel arrivals to identify any measurable traffic delays on SH 146 and SH 225 near the Bayport and Barbours Cut terminals. No relationship between reduced traffic speeds and vessel arrivals, vessel days in port, number of vessels in port, or port closure days, including lagging effects of port closures were found.

The results of this analysis indicate that terminals are able to efficiently handle events that disrupt cargo shipments at the Port of Houston without drastically impacting highway traffic. This suggests that the surrounding highway capacity is sufficiently robust for freight transportation.

A more in depth study of the December 2007 fog event is included in Appendix C.

Other Mode System Assessment

Similar to railroads, other modes that are owned and operated by private companies are highly resilient out of necessity. However, this assessment also showed that in the case of the Port of Houston, the surrounding public roadway infrastructure is also highly resilient during events that cause abnormal fluctuations in truck traffic.

Representatives of the marine, air and pipeline modes that were interviewed as part of this plan indicated that coordination by all affected agencies is critical during events. One terminal operator noted that all mission critical personnel required to bring a terminal back on-line should be given an identification card that would allow them to pass through roadblocks or road closures during the terminal start-up phase. Not all of these mission critical employees have the required identification to get to the terminal if



necessary. TxDOT personnel are often responsible for road closures but rely on local and state law enforcement to monitor compliance with the closures.

This request parallels that made by railroads suggesting that communication between the freight transportation community and law enforcement/emergency management agencies is critical to maintaining a highly resilient transportation system.

Section 6. Advancing the Resilient Freight Transportation System

The highway system managed by TxDOT is a major component of the state's resilient freight transportation network. The interstate system and major US highways are the key corridors that carry truck-based freight. As discussed in this plan, the state's highway infrastructure provides a robust and redundant system. However, the highway system is only one component of the overall freight transportation system that carries freight in Texas. The network of railroads, marine ports, airports, and pipelines complete the overall system. These other modes have shown they are highly resilient by their ability to swiftly recover from past events.

Over 4,500 miles of primary highway corridors were assessed to measure the preparedness of the Texas highway freight transportation system. These corridors carry from 2,000 to over 11,000 trucks per day. While some congestion exists, mainly near population centers, the overall primary corridors experience only some stop-n-go traffic. While there are physical constraints on the primary system, many of these do not prohibit standard highway truck travel but these locations should be prioritized for upgrades to further enhance the robustness of the primary highway corridors. The overall statewide hazard rating is 2.8 with flooding as the most likely hazard. This overall rating is categorized as a low risk. Operationally and physically the highway corridors are very resilient with a low level of hazard risk.

The Texas rail system is highly resilient out of necessity. Railroads cannot let damage to their system impact their operations for extended periods or they will lose customers. Similar to railroads, other modes that are owned and operated by private companies are highly resilient for the same reasons. However, this assessment also showed that in the case of the Port of Houston, the surrounding public roadway infrastructure is also highly resilient during events that cause abnormal fluctuations in truck traffic.

Strategies

While the overall freight transportation system in Texas was found to be robust and redundant, there are actions that TxDOT can take in a continued effort to improve freight resilience in Texas. Based on the research completed and interviews with other states and the private sector, four strategies for advancing the resilient freight transportation system were developed.

Strategy 1: Support planning for a resilient, well-maintained freight transportation network

- Incorporate freight resiliency into traditional transportation planning and programming
- Include other modes in planning efforts to increase awareness of system-wide needs

The Texas Statewide Long-Range Transportation Plan 2035 (SLRTP) is a collaborative, multimodal plan that outlines needed transportation projects and

services. The current SLRTP considers freight needs for all modes. Future updates to the SLRTP will continue to incorporate freight transportation but consideration of resiliency will increase benefits to the freight transportation system.

Strategy 2: Prioritize infrastructure enhancements to improve the freight resilience of Texas highways

- Utilize corridor assessments to identify operational bottlenecks and physical constraints
- Investigate ways to fund improvements needed for other modes

The corridor assessments illustrated areas of operational constraints which mainly focused on a need for additional capacity on secondary routes and physical constraints focused on vertical, lateral and weight restrictions. Projects and services related to improving operational and physical constraints for freight resiliency should be considered by Metropolitan Planning Organizations in their Transportation Improvement Programs (TIPs) and in TxDOT's Statewide TIP (STIP). Leveraging partnerships in creative ways should be investigated to assist the private sector in identifying funds for other modal improvements.

Strategy 3: Improve access to data, information, and people needed for effective resiliency planning

- Understand baseline data and continue to build information database
- Define local issues and needs
- Recruit key players to boost effectiveness of planning

TxDOT is completing updates to its Statewide Travel Demand Model which will greatly enhance the ability to accurately measure the capacity needs of the primary and secondary corridors into the future. The Texas Permitting & Routing Optimization System (TxPROS) is an integrated GIS-based mapping system with real time restriction management that provides "true" automated routing for transporting permitted loads on state maintained roads. Once the TxPROS database is completed it will prove vital to assisting TxDOT in identifying physical constraints.

Understanding the statewide system is the first step in resiliency planning but there are local issues and needs that should be considered especially on secondary corridors. Representatives of MPOs and COGs, system users, and emergency managers can bring insight and resources to improve on-going resiliency planning.

Strategy 4: Communicate before, during, and after events

- Provide up-to-date, comprehensive status reports
- Hold coordinating meetings among critical sector groups
- Engage the private sector

Communication was overwhelmingly viewed as the primary need of users and system managers before, during, and after an event that impacts the freight



transportation system. TxDOT was viewed as an organization that could act in a support role to assist the private sector to recover from man-made or natural freight resiliency events. The lack of a central location for all transportation-related activities during a severe disruption suggests that TxDOT might consider creating a tool that assists shippers and transportation providers when considering various options. A single location providing information on such matters as traffic conditions, barge, and rail availability, port status, and emergency truck stop information will enhance freight resiliency in the state. Engaging the private sector allows TxDOT to target the right forum and messages to communicate with users.

Section 7. Approach for Future Stages

The Stage 1 SFR Plan focused on setting the context and purpose of resiliency planning for Texas, while identifying and assessing the state's freight transportation corridors. The Stage 1 goal was to have a freight transportation system prepared to keep freight moving during an event. Texas corridors are robust, and an extensive system of redundant corridors is available. Many stakeholders indicated that communication is important to freight transportation system resilience. The results of the Stage 1 plan indicate that the overall Texas freight transportation system is prepared for an event but there are physical and institutional areas that could be improved to provide higher levels of resiliency.

The Stage 2 SFR Plan should build on the recommendations of stakeholders to develop the necessary communication and implementation plan, to provide a resilient transportation system during and after an event. While stakeholders provided some information on their needs during an event, any communication plan should be developed with their input. Utilizing stakeholders during Stage 2 will guide the creation of a communication network targeted to sending appropriate and timely messages to shippers and carriers. Stage 2 should also investigate ways that TxDOT can expand its coordination efforts with state emergency management agencies to consider the needs of freight. During response and recovery efforts TxDOT can assist freight providers by bringing attention to their needs with other agencies.

Stage 2 Goal: To have a responsive framework to address shipper and carrier needs as an event occurs and to recover the freight transportation system as quickly as possible.

- Institute a communications network targeted to sending messages to shippers and carriers.
- Rapidly return the freight transportation system to normal operations by deploying all available and appropriate resources in coordination with the appropriate chain of command.

Stage 3 is an on-going, internal function for TxDOT. Continuous feedback after real events will improve the plan and ensure its relevance. After an event, freight considerations should be included in summary reporting so that efforts are documented and lessons drawn from the experience. In the absence of an event, TxDOT should continually evaluate resilience on a regular schedule and incorporate feedback so that consideration of the Texas economy stays in the forefront.

Stage 3 Goal: To have a flexible, relevant plan that is used to improve freight mobility in Texas.

- Identify funding to implement infrastructure solutions that increase the robustness and redundancy of the freight transportation system.
- Build partnerships with emergency management to ensure that economic considerations are appropriately incorporated into response and recovery.

- 
- Evaluate resilience on a regular schedule and incorporate feedback into plan updates.



Definitions

B

Business Continuity Plan: a logistical plan for how an organization will recover and restore partially or completely interrupted critical functions within a predetermined time after a disaster or extended disruption.

C

Corridor: a broad geographical band with no predefined size or scale that follows a general directional flow connecting major sources of trips.

D

Disruption: what occurs when the incident happens, i.e. a highway is closed due to mudslide or a rail line is out of service due to flooding.

Degree of disruption: is measured as minor, moderate or major based on the duration of time it takes to detect, respond, and recover from the incident.

Duration of disruption: varies depending on the severity of the incident; i.e. minor to moderate to major. Disruptions that cause a change in freight travel patterns are the focus rather than a short-term or minor closure where a driver may just "wait it out."

E

Event: overall occurrence or the complete cycle illustrated in the resilience triangle.

Catastrophic events: result in extraordinary loss of life and property. These events cause national-level impacts over prolonged periods that exceed capabilities of normal resources.

Episodic event: an unpredictable occurrence yet manageable with available resources.

Recurring events: such as traffic congestion are routine and freight shippers and carriers are aware of these constraints.

I

Incident: the specific action that occurs at a defined point in time that triggers a change in the transportation system. For instance, when the hurricane makes landfall or a terrorist attack occurs.

L



Logistics management: that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements.

M

Managing organization: responsible party for all aspects of the freight transportation system – operations, maintenance, and communication. A state DOT is the managing organization for the highway transportation network while the railroads are not only the user of the rail network but also the managing organization.

P

Physical infrastructure: highways, railroads, bridges, ports, and all other assets. These are the traditional elements that are considered part of the freight transportation system.

R

Rapidity: a function of the time needed to restore the transportation system functionality.

Resilience: the capability of the system to prevent or protect against significant multi-hazard threats and incidents and the ability to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security. Also called **Resiliency**.

Freight transportation system resilience: the ability for the system to absorb the consequences of disruptions, to reduce the impacts of disruptions and maintain freight mobility.

Redundant: the availability of alternate routes or modes.

Resourcefulness: the ability to source material and other resources to restore operation.

Robust: ability to withstand an incident without significant failure.

Route: a specific, established line of travel between points such as a highway or rail line.

Primary highway route: the physical route representing a key freight corridor with statewide significance connecting major activity nodes within Texas.

Secondary highway route: an alternate or redundant route to the primary highway route providing access to the same major activity nodes during a resiliency event.

Connector highway route: the highway link between the primary and secondary highway routes allowing for segmentation and travel between the routes.

S



Supply chain management: a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed in the right quantities, to the right locations, and at the right time, in order to minimize systemwide costs while satisfying service level requirements.

T

Twenty-Foot Equivalent Unit: a unit of measure of containerized trade. One TEU equals one 20-foot marine container and two TEU equals one 40-foot marine container.

U

Users: vehicles operating on the network and the managers that direct their travel.

List of Acronyms

ADT	Average Daily Traffic
ASCE	American Society of Civil Engineers
BNSF	BNSF Railway
CIKR	Critical Infrastructure/Key Resources
COG	Council of Governments
CTL	Center for Transportation and Logistics
CSCMP	Council of Supply Chain Management Professionals
DFW	Dallas-Fort Worth Airport
DHS	Department of Homeland Security
DOT	Department of Transportation
TxDOT	Texas Department of Transportation
WashDOT	Washington State Department of Transportation
USDOT	United States Department of Transportation
FEMA	Federal Emergency Management Administration
GDP	Gross Domestic Product
GIWW	Gulf Intercoastal Waterway
KCS	Kansas City Southern Railway
MCEER Research	Multidisciplinary Center for Earthquake Engineering
MIT	Massachusetts Institute of Technology
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
NIPP	National Infrastructure Protection Plan
NPG	National Preparedness Guide
NRF	National Response Framework
SFR	Statewide Freight Resiliency
SLRTP	Statewide Long-Range Transportation Plan
STIP	Statewide Transportation Improvement Program
STRAHNET	Strategic Highway Network
STRACNET	Strategic Rail Corridor Network
TEU	Twenty-foot Equivalent Units
TIP	Transportation Improvement Program
TPP	Transportation Planning and Programming



TSA	Transportation Security Administration
TxPROS	Texas Permitting & Routing Optimization System
UP	Union Pacific Railroad
VMT	Vehicle Miles Traveled

Statewide Freight Resiliency Plan Advisory Committee

The Texas Department of Transportation assembled a committee of government officials, industry experts and freight users to assist in providing input and feedback in the development of the Stage 1 Statewide Freight Resiliency Plan. The committee met via webinar three times during the course of the project in conjunction with statewide stakeholders interested in freight planning.

Statewide Freight Resiliency Plan Advisory Committee	
Advisory Committee Member	Organization
Bradley P. Alm	HEB Grocery
Pete Baldwin	Office of Emergency Management - Austin
Carla Baze	Texas Department of Transportation - Maintenance Division
Lupita R. Canales	A. R. Canales International Brokers, Inc.
Frank Cantu	Department of Public Safety - Division of Emergency Management
Maureen Crocker	Gulf Coast Freight Rail District
Roldolfo Delgado	National Customs Brokers and Forwarders Association of America
Alec G. Dreyer	Port of Houston Authority
Reeves Easley-McPherson	Panhandle Regional Planning Commission
David C. Fisher	Port of Beaumont
Steve George	Fort Worth and Western Railroad Company
Dan Kessler	North Central Texas Council of Governments
John P. LaRue	Port of Corpus Christi
Otis J. Latin, Sr.	Office of Homeland Security and Emergency Management - Austin
Rob Looney	Texas Oil and Gas Association
Eduardo Mendoza, PE, PTOE	City of McAllen/TexITE South Texas
Jim Nance	Texas Farm Bureau
John Porche	Texas Motor Transportation Association (Corpus Christi)
John Simsen	Galveston County Office of Emergency Management
Richard Smith, PE	City of Houston Traffic Eng./ Houston Area TexITE
Bob White	Bob White Express Trucking

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Appendix A: State DOT Interviews

Peer State Interview Summary: Washington State DOT

A telephone interview was conducted on November 17, 2009 with the Washington State Department of Transportation (WSDOT). Barbara Ivanov, Director Freight Systems Division, represented WSDOT on the call. Sara Clark and Mark Kenneally from TranSystems hosted the call. Jennifer Moczygemba and Orlando Jamandre from TxDOT attended.

The following information was shared by Ms. Ivanov during the interview.

Freight Planning

The point of freight planning in Washington is to serve the economic needs of the state and provide a specific report for freight within the greater statewide comprehensive planning process. Washington has identified three freight focus areas:

- Global Gateways – pass through Asian trade, primarily marine-rail modes
- Made in Washington – manufacturing, timber, agribusiness, domestic US markets
- Delivering Goods to You – urban markets for things like food, fuel, trash collection

The DOT is interested in knowing what logistics activities support these three groups using the least amount of public dollars. Because freight is not funded, Ms. Ivanov acts as an advocate. Her position is to focus on supporting the regional and statewide economy. Ms. Ivanov likes to say that freight is all about business – freight doesn't have a social life.

Implementing freight programs is complicated by the lack of funding or legislative mandate. The transportation Secretary has a five pronged approach to integrate freight in the department. The five areas of integration are: design (trucks require wider turn radius), traffic (trucks accelerate slower than passenger cars), planning, emergency management and communications.

Role of Resiliency/Event Based

Freight resiliency became a topic of interest in Washington after Ms. Ivanov attended a Council of Supply Chain Management Professionals (CSCMP) conference. She attended this conference to understand the shipper's perspective on transportation. She attended a session by Dr. Yossi Sheffi on enterprise resilience and asked if he would consider working with the public sector. The plan developed by Sheffi and MIT developed 8 actionable steps to a resilient system for Washington but the steps can be applied anywhere.

She reported several barriers to having a resilient system. First, the DOT owns and operates only the highway system. In urban areas, barriers range from bottlenecks and capacity gaps to truck travel time and reliability. Physical features include design elements such as entrance ramps. Statewide barriers include the lack of access. Access problems are caused by the lack of connections through mountainous regions



which cuts the east side of the state off from the west side. This occurs mainly during weather-related events.

Washington has no redundant routes. The only N/S route is IH 5 and the only E/W route is IH 90. There are no other routes that can replace the capacity of these interstates. WSDOT is not pursuing redundancy as a strategy because it is too expensive but they do continue to look for an infrastructure solution for IH 5 (robustness). However, they do have incidents that impact freight travel so they must work around this known weakness. The strategy they have chosen is to provide information or to communicate with shippers to assist them in making travel decisions.

Ms. Ivanov rated the response of the DOT at a 10/9.9 for recovery activities. She feels that the staff in the field making repairs does an excellent job with the resources at hand.

Ms. Ivanov stated that it is her opinion that railroads are very good at resiliency. They are losing dollars everyday a line is out of service so they put all resources into action to make repairs quickly. All they typically ask of the DOT is to provide access to their facility.

Relationships are a key component to successful freight planning in Washington. The DOT has a very disciplined outreach program for shippers and carriers. The staff goes to the shipper's place of business on a regular basis to gather "customer intelligence."

They have gotten better at communications over time. They started with a contact list of 600 shippers, manufacturers, wholesalers, etc. built through their planning program. This list was housed on Ms. Ivanov's computer which was not flexible enough to provide good communication. Today they contract with a commercial service, GovDelivery, to deliver messages to freight stakeholders.

One challenge is building situational knowledge within the organization. It is difficult to educate staff to know what information is important. It is important to provide predictive information through the freight notification system. They have found that information dissemination before the event occurs (e.g., IH 5 will close in 4 hours) is more valuable. To help build internal knowledge, they debrief with shippers each year after the storm season to find ways to improve communication and response.

The national system for emergency response is not set up to acknowledge economics. She submits that once life and safety are taken care of economics should be considered.

Their Commercial Vehicle Pass System authorizes the use of the near detour route during an event. It is a priority system that carriers can apply for online.

They have developed a State Freight Model that is loaded with supply chain information, corridor level information, and evaluates industry sectors that are at high risk.



Interview Assessment

Washington has done a significant amount of work related to freight resiliency and it appears that the state recognizes that freight is important to the economy. It is interesting to note, however, that Washington appears to focus on the response and recovery stages of an event and place less emphasis on preparedness. However, they may approach preparedness differently because, as Ms. Ivanov noted, they have very few (if any) redundant routes available to them.

The real benefit of this interview is understanding how or if the information provided by Washington applies to Texas. It is clearly evident that Texas infrastructure is different from Washington. Texas has numerous redundant routes unlike the network in Washington. For instance, the frontage road system provides immediate redundancy and US and State highways provide detour routes. One lesson learned from this interview is that in the case where Texas does not have a redundant route it will be important to look at communication of predictive information.

Washington also faces the challenge of limited or no funding for freight-related projects. It was noted that in the situation where no funding for infrastructure is available there are "free" things to look at like operations, traffic management, and communication. However, these items continue to focus on response and recovery functions where this plan for Texas is focused on preparedness and measuring the system's resilience for freight today.

Ms. Ivanov mentioned that closing IH 5 for recurring events (i.e., flooding) due to design constraints is a known issue that impacts freight. Transportation systems are constantly assessed for constraints however an assessment from the freight resilience perspective has never been undertaken on a statewide basis in Texas. This interview pointed out the importance of being aware of infrastructure constraints that impact the freight before an event occurs.

Peer State Interview Summary: California DOT

A telephone interview was conducted on November 23, 2009 with the California Department of Transportation (Caltrans). Richard Nordahl, Chief, Office of Goods Movement, represented Caltrans on the call. Sara Clark and Sarah Cross from TranSystems hosted the call. Michele Fell-Casale from Caltrans and Raul Cantu and Orlando Jamandre from TxDOT attended.

The following information was shared by Mr. Nordahl during the interview.

Freight Planning

The approach to freight planning in California is focused on system planning. They look at what is needed by the system to move freight to an efficient standard (highway, rail, sea, border, and air). Their focus is on mobility, velocity, reliability, throughput, safety, economic development, and the environment.



There are many different hands involved from the headquarters office to the twelve districts. Headquarters develops the statewide plans including the goods movement action plan. The statewide rail plan has a freight element in it. Currently they are conducting an air cargo study. There is not a statewide advisory committee but the districts work with the MPOs (SCAG and SanDAG, primarily) on their regional freight advisory committees. Caltrans has direct contacts with the seaports, trucking firms, and railroads. Primary contact with trucking is through their traffic operations division on OS/OW permits.

California's top freight priorities for policy are Mobility, Economic Development, and Improving Environmental Quality. The top project priorities are outlined in the Goods Movement Action program. In November 2006 a \$19.9 Billion bond program was approved that included \$2 Billion in funding for freight projects. The Commission set up a bid program in 4 regions of the state plus a statewide region. Each region had a list of projects which resulted in a total of 79 projects valued at \$3.1 Billion. Despite being over programmed, the bond program it is slowly moving ahead.

Role of Resiliency/Event Based

General work on freight resiliency in California has occurred at various points. In 1995, a study on life line routes identified 30 key routes for people and goods movement. Each major district has had an emergency plan since the early 1980s. The major seaports have plans in place with the most recent adopted in early November by San Diego. The seaports are generally landlord ports so their plans are tied to the city's plan. Generally, these are referred to as Business Continuity or Disaster Preparedness plans.

Mr. Nordahl said that California's definition for freight resiliency is similar to the definition provided for the Texas plan. He stated that their definition would be to maintain mobility throughout an event. The priority for emergency management agencies is to get back to normal but there is no focus on freight. He indicated that Washington's information system was very good. California's system is fragmented and not run by Caltrans.

According to Mr. Nordahl's experience, California's transportation system is resilient with an asterisk. In urban areas there are redundant routes or a duplicate system. The exceptions are mountain passes and rural areas. For instance, from LA to the San Joaquin Valley there is only IH 5 as a primary route. The primary rail route is the Union Pacific Railroad (UP) with a little more duplication than highway. In rural areas there are many routes vulnerable to landslides that have alternate routes but they are very circuitous.

Michele shared that recently a bypass was built on the 101 highway around "Confusion Hill" due to numerous mudslides that would close the road for up to 5 days at a time.

The state has made efforts to increase the robustness of the system through a seismic retrofit program. Ports have made efforts to strengthen their facilities through deep piles but the test will come with the next earthquake.

Several case studies were prepared by Mr. Nordahl and shared on the call.

Loma Prieta Earthquake (Bay Area), October 1989

This earthquake caused an entire section of IH 880/Cyprus Freeway to collapse. This severed the second highest volume truck route in California. There was enough of an alternative network that trucks were moving relatively quickly but circumstances were not ideal. A segment of the Bay Bridge also collapsed requiring traffic to be sent to other bridges, again not an ideal situation. At this time cell phones were not widely in use so communications were difficult. One major concern was that communication systems (land line telephone and television) would fail.

Northridge Earthquake, November 1994

The epicenter of this earthquake was within 5 miles of the IH 5/SR 14 interchange which is over the main N/S UP line. This section of highway had a major collapse which happened at a time with little traffic. The UP had to reroute all traffic to two other corridors. The highway was completely cut off and trucks had to travel 20 or more miles out of their way to bypass the collapsed section. Communications were a weak element in this disaster. However, there were daily and then weekly bulletins to the trucking industry identifying open and closed routes and the primary detours.

Railroad

Mr. Nordahl shared that the railroads by and large take care of their own issues with cooperation from emergency management and the public utilities commission. But for as much as they are investing, they still have resiliency problems. A direct example in California occurred two-years ago when a major fire on the bridge over the American River cut the UP's east-west and north-south mainlines. The UP asked Caltrans for permission to move OS/OW loads of construction materials and equipment necessary to reconstruct the bridge. The department expedited permits and provided safety escorts. The UP had the line partially operational in 4 weeks and completely open in 2 months. The department "bent over backwards" to make the permits happen because of mode shift concerns and because the trackage was critical for passenger rail routes in the state.

Overall Mr. Nordahl reports that California's infrastructure has good resiliency from his perspective as the head of statewide goods movement planning. Communication and organization is slightly weaker. He shared that operations may have a different perspective. He emphasized that communications is the weakest link the resiliency chain between the institutions responding. The network is there but everyone has their own plan and coordination and trust are lacking. Michele shared that the basic neural network is present and can be activated for use during an event but that is easier said than done.

Interview Assessment

Although California has not done anything under the specific title of "freight resiliency," they have experienced events that would be classified as a resilience event and they have put in place programs to aid resilience. California has redundant corridors in many areas and in the areas where they don't exist they have considered ways to



improve robustness. Caltrans also approaches freight from a system perspective and they act as a supporting managing organization to railroads and seaports.

During the interview communication was mentioned as an important element of resilience. However, it was mentioned in the context of response which is not a part of this phase of the plan yet a key element to consider in future phases. Washington's efforts to communicate messages to the freight community were mentioned. California confirmed that Washington is a leader in freight resilience by mentioning their efforts during this interview.

This interview reinforced that during the planning stages redundancy and robustness are key elements of resilience.

Peer State Interview Summary: Minnesota DOT

A telephone interview was conducted on January 21, 2010, with the Minnesota Department of Transportation (MnDOT). John Tompkins, Office of Freight, Rail, and Waterways, represented MnDOT on the call. Sara Clark from TranSystems hosted the call. Raul Cantu from TxDOT attended.

The following information was shared by Mr. Tompkins during the interview.

Freight Planning

Minnesota has a combined freight and commercial vehicle operations office. In the 1980s, a freight initiative created an advisory committee so that the private sector could have a voice in the planning process. In the mid-80s, freight was an afterthought in statewide planning but it has matured to a higher position. Based on the success of this initiative, the freight office evolved into programming. The primary programs are: rail improvement, port development, and truck size and weight. The rail program includes \$2 million per year in capital funds to shippers to make improvements or expand their rail infrastructure. The port development program receives funds from the state legislature.

In 2002, a statewide freight plan was initiated. A consultant was hired in 2004 to develop a policy statement. In 2005, the policy statement was issued along with 10 strategies focused on mobility, regulations, and operations. Since completing the statewide plan, sub-plans at the county and regional levels were initiated. Six of nine plans are complete and the Metro study will be initiated soon. The Metro plan will emphasize elements included in draft federal legislation which highlights freight so that Minnesota can be positioned for future funding. An update to the statewide plan will occur in 2012.

MnDOT has completed regional studies because different areas of the state have vastly different needs for freight transportation based on the industries and populations served. In their regional studies they identified freight routes by counts and through talking to industry.



One issue that was identified during the regional studies was a lack of district coordination on prioritizing routes. This was evident in snow removal operations. If a route is present in two districts, the priority of snow removal on that route may not be the same in both districts. For instance, it might be plowed right away in District A but not for several days in District B. The regional plans emphasized the need for coordinating the interregional significance of freight routes.

Role of Resiliency/Event Based

Mr. Tompkins shared that when events happen it illuminates that something needs to be done; action needs to be initiated. Resiliency is not a formal part of the MnDOT planning process however based on recent events it may become more important. A large portion of the interview focused on the events surrounding the August 1, 2007, collapse of the eight-lane, IH 35 bridge over the Mississippi River. The bridge collapse immediately closed this route to traffic and the highway was subsequently closed until September 2008 when the reconstruction was complete.

Mr. Tompkins reported that within several hours of the bridge collapse MnDOT had added lanes to adjacent routes and rerouted traffic around the bridge using their ITS system and variable message signs. Within 48 hours, the traffic diversion was adequately providing capacity to the rerouted traffic. Most of the detours were on Interstates 35W/94. Other bypass routes were IH 29 around downtown which is a heavy industrial area.

The incident heavily impacted passenger traffic but shippers and carriers did feel the effects as well. Mr. Tompkins noted that each shipper and carrier had their own approach to the road closure. Since the collapse occurred in the metropolitan area, there were numerous routes that truck drivers, small package carriers and other highway freight carriers were able to utilize. Drivers reported using MnDOT's Web site which was reporting detour and real-time traffic information three to four-4 days after the incident for the new routes. Most drivers had knowledge of local routes and found new routes to use during reconstruction.

The Minnesota Commissioner reached out to shippers and carriers through the long-established Minnesota Freight Advisory Committee. He sought information from them to see how they were dealing with the detours. MnDOT used their feedback to improve the Web site and their traffic management.

One member of the committee, FedEx, reported that they changed their shipment consolidation point during reconstruction. Their existing facility was close to the bridge and it made more sense for their operations to move this function to a suburban facility. MnDOT learned that it was important to communicate the duration of the closure so that shippers could be knowledgeable of the need to change their operations or, if possible, wait for a return to normal (or better) operations.

Mr. Tompkins reported that MnDOT used several means to add capacity to the overall systems during the extended time the route was closed. Shoulders were used to add



capacity on several routes. Some shoulders that were already designed to handle transit vehicles were opened to all traffic. On one detour route, traffic signals and intersections were shut down to give priority to through movements. This was done in an industrial area and required trucks to reroute to access their destination. The reroutes were relatively short but did add distance to trips. Mr. Cantu asked how the infrastructure handled the additional traffic. Most shoulders were not built for traffic and they had additional wear that needed repair. Overall, the routes were not degraded by the additional traffic. Traveler services (i.e., food, fuel) were generally available.

Technology was also used to build capacity through information. The 511 service and MnDOT Web site were constantly updated. Mr. Tompkins stated that a vigilant media made traffic conditions a “reality show.” Message boards were constantly updated to describe congestion and help people make better decisions. Ramp metering was also used more effectively to manage traffic.

MnDOT tracked the system performance and calculated the industry cost per mile of the closure using FHWA methodology. The Minnesota Trucking Association calculated a higher value. Even with higher costs, Mr. Tompkins indicated there was not a significant mode shift away from truck. The type of trips and corridor are dependent on truck moves. More consolidation and asset relocation was observed.

The Inland Waterway (Upper Mississippi River) was closed for about one month after the collapse for recovery and debris clearing. When the lock and dam was operated, the water flow disrupted the recovery efforts. Communication with the barge industry was conducted through industry associations. There is limited shipping on the Upper Mississippi so this was not a prominent issue. There were reports that a cement industry had to use trucks for a short period of time.

MnDOT is not formally discussing changing their operations to be more prepared for a resiliency event. They have documented their Critical Infrastructure/Key Resources for freight in the state through an asset management process. They are investigating an email alert system similar to the one used in Washington State.

Interview Assessment

Minnesota has not completed any formal “freight resiliency” planning; however, they have experience with events that would be classified as a resilience event like the recent IH 35 bridge collapse and more common snow events.

MnDOT heavily relies on technology to build capacity on the transportation network. They also are willing to utilize the infrastructure in ways not originally intended to support an “emergency” use – driving on shoulders and shutting down intersections. Communication was also reported as an important component to successfully returning operations to a normal state.

Much of the discussion in this interview centered on response and recovery which is not a central focus of the Texas Stage 1SFR Plan. However, the information obtained will



help direct future stages of resiliency planning. The information on MnDOT's regional plans and the need to understand each district's priority is valuable to note for this plan.



Appendix B: Private Sector Interviews



Introduction

The Texas Department of Transportation (TxDOT) recognizes that the highway system is a major component of a resilient freight network. As the managing organization responsible for maintaining the State's highways and the Gulf Intracoastal Waterway, TxDOT is developing a Statewide Freight Resiliency (SFR) Plan to provide a comprehensive framework for identifying key freight infrastructure corridors and develop strategies to ensure a resilient freight transportation network in the State of Texas.

A part of developing the SFR Plan, private-sector representatives were interviewed to provide input from the user perspective. The interviews assess shipper and carrier continuity planning for moderate to major transportation service disruptions in Texas, causing substitute routing or modal choice decisions. A service disruption is defined for interviewees as blockages to any roadway, railway, water port, border crossing or any stoppage in their existing supply chain that substantially alters their transportation network in Texas. The focus of the interviews is on events that will likely divert freight traffic from affected routes to alternative key Texas roadways; however, rail and waterborne modes are also discussed.

Key Findings on Texas Private-Sector Freight Resiliency Planning

Companies involved in the movement of freight in Texas have experience with freight corridor disruptions within the state; one of the most commonly cited events was Hurricane Rita in 2005. This and other disruptions have increased awareness of the importance of freight resiliency planning; however, the level of planning detail varies among interviewees.

Two categories of companies were interviewed: shippers who own the cargo being transported and transportation companies that actually move the cargo. Shippers who were interviewed took a strategic approach to freight resiliency planning that included anticipation of the types of disruptions and anticipated recovery periods based on the severity of the disruption. The responsibility to actually carry out the freight resiliency plan was viewed to be the responsibility of the transportation company that handles the goods.

Transportation companies took a tactical approach to freight resiliency planning, which relies on reacting to actual conditions presented at the time of a disruption. The tactical response involves identifying alternative routes based on knowledge of local roadways and real-time traffic conditions of those routes. The combination of both the strategic and tactical approach to freight resiliency planning in Texas described by interviewees provides a well-rounded base of information for TxDOT to consider when developing the plan.

Key findings are:

- While most companies who were interviewed do not have a formal resiliency plan, they are aware of the steps needed to respond to events that cause extended transportation disruptions based on day-to-day operational experience and recent natural disasters.
- Transportation companies, especially trucking companies, are viewed by shippers as responsible for executing resiliency plans on behalf of shippers.
- Unanticipated or high risk/low probability events have the potential to cause the most disruption in the short term. Most companies have plans to address longer term interruptions, while short term interruptions of up to one week will likely receive reactive responses, mostly initiated by transportation service providers.
- Consumer product consumption, especially non-discretionary product consumption drives freight traffic in areas experiencing wide-spread damage. Normal freight volume resumes gradually as regions recover and consumer demand returns.
- As expected, Texas interstates and US highways are of the greatest concern, simply due to the amount of freight that moves on these corridors.
- Inbound out-of-state truck traffic will increase if access to key Texas distribution centers, ports or other cargo distribution hubs is disrupted, as cargo will source (be brought in) from distribution centers from nearby States, in some cases.
- Alternative transportation modes can be used in emergency response situations. Barges, for example may be considered when truck and rail is unavailable, and vice versa.
- Too much regulation imposed by TxDOT was viewed negatively. Regulating traffic based on criteria set by a government agency was of concern, because shippers felt that they would do a better job of prioritizing the types of shipments that should be transported during severe route disruptions.
- TxDOT was viewed as having a support role in assisting the private sector to recover from conditions caused by man-made or natural disasters. Communication was overwhelmingly the primary need expressed. Specific assistance recommended was to provide accurate and timely information about alternative routing, estimated transit times, and perhaps establishing emergency commercial routes in some cases. Clear communication channels between TxDOT and major transportation companies operating in Texas should be emphasized.
- In light of interviewee comments noting the lack of a central location for all transportation-related activities during a severe disruption, TxDOT should consider creating an information clearinghouse to assist shippers and transportation providers when considering various options. A single location providing information on such things like traffic conditions, barge and rail availability, port status, and emergency truck stop information is recommended. Communication processes used by the Texas Fuel Team may be a good benchmark.

Methodology

TranSystems interviewed twenty-one companies involved in the movement of freight in and through Texas, representing shippers⁹, truckers, railroads, ocean lines, barge operators and ocean terminals. Interviews were conducted by telephone and in person in August and September 2010. Interviewees were chosen based on their operational experience in Texas or their involvement with the development of resiliency planning in their organizations. The twenty-one interviews conducted are sufficient to reveal high-level issues relating to private sector resiliency planning.

The semi-structured interviews were designed to provide interviewees with the opportunity to offer input that may be specific to their experience and to allow additional unanticipated themes to be included in the study. The following points were covered:

- Confirmation of the existence of a resiliency plan (sometimes referred to as continuity plan)
- Key factors to consider when developing a resiliency plan
- Understanding what events trigger the plan execution
- Criteria for choosing alternative routing
- Alternative origin cargo sourcing capabilities
- Texas truck, rail or barge routes that are of most concern
- The possibility of switching transportation modes (e.g. truck to rail) as part of the plan
- Suggestions for TxDOT

Industry Segment	Number
Barge Company	2
Energy Association	1
Ocean Carrier	2
Ports and Terminals	2
Shipper	3
Railroad	2
Rail District	1
Third Party Logistics Provider	2
Trucking Association	2

⁹ A shipper is defined as a consignor, exporter, or seller (who may be the same or different parties) named in the shipping documents as the party responsible for initiating a shipment, and who may also bear the freight cost (e.g. Wal-Mart, Proctor and Gamble, Dell).

Truckload Carrier	4
Total	21

Source: TranSystems.

Plan Components

One interviewee noted a familiar axiom - "The plan is nothing. Planning is everything." The degree of severity and the resulting implications are not known until a resiliency event occurs. The power of a resiliency plan is an enhanced private sector understanding of emergency operations and it increases the likelihood of an effective response to emergency conditions. Based on interview responses, overall resiliency plans generally follow the sequence below:

1. Prepare: Action plans are developed based on events that are prioritized by probability and degree of disruption. Planning is most likely to occur for a highly probable event that will result in a longer term disruption. Hurricanes, for example, were commonly mentioned in the interviews as a likely event.
2. Respond and Recover: Plans are executed based on actual conditions on the ground and the recovery option that is initiated is based on the duration of the disruption. Initial response focuses on safety and clearing cargo from affected areas Recovery addresses longer term operations.
3. Communicate: Ongoing communication plans to coordinate all actions addressing safety, traffic, and alternative routing decisions are an integral part of the overall resiliency plan.

The result of the above is that the initial response to a major event considers the safety of transportation personnel and cargo security. Communicating alternative routing, secure depots, and the status of facilities is the main concern. According to interviewees, truck drivers, dispatchers, and other transportation personnel are heavily relied upon during the initial stages of a disruption due to their knowledge of the freight transportation network (e.g., local roadways, inland waterways). Virtually all interviewees suggest that TxDOT plays a critical role in effectively disseminating timely information about blockages, alternative routes, and expected transit times throughout any major interruption to transportation routes in Texas.

Not all interviewees have a resiliency plan. Their interest in having a plan, whether the State's or private, depends on the freight value, "criticality" of freight and size of the operation. A small trucking company of four employees said they simply cannot commit the resources needed to develop something as complex as a resiliency plan. The implication is that, in light of the large number of owner/operator truckers and small business, the vast majority of companies likely do not have resiliency plans

Resiliency Plan Participants

Private-sector resiliency plans combine shipper and transportation provider input to comprise the overall resiliency plan. Shipper and transportation provider plans differ in that shippers have a strategic focus and transportation providers have a tactical focus.

Cargo Shippers

Interview responses suggest that shipper strategies consider the entire supply chain, including inventory and warehousing requirements, when planning for service disruptions to their freight transportation network. They are most concerned with positioning products into areas where they are needed in a timely fashion. As one interviewee advised, “The cost of stock-outs¹⁰ outweighs additional re-routing costs.”

The actual routing of cargo is left to the trucking or rail providers, who are often relied upon to deliver routing alternatives and to develop plans that will meet service standards.

A shipper’s strategic approach to resiliency planning considers several factors:

- Products are prioritized to meet the severity of the situation. This is most important for areas experiencing wide-spread damage, such as a region damaged by a hurricane.
 - The amount of safety stock¹¹ on hand determines the need to truck additional cargo.
 - Non-discretionary items, such as food, water, and batteries, receive the highest priority. These items were mentioned as being required almost immediately, and remain a priority for the duration of an event. A shipper who was interviewed indicated that his company participates on a Texas emergency response team that coordinates the delivery of these types of items in emergency situations.
 - Some discretionary cargoes, like toys or some consumer recreational items, may be intentionally delayed until conditions clear, as the demand for these types of items tends to be low in disaster areas.
- Alternative sourcing areas and gateways are identified.
 - All alternatives for product sourcing are identified, so that a disruption to one source may be overcome by sourcing from an available alternative.
 - Some smaller manufacturers may not have alternatives and would not be able to recover as quickly as larger companies with regional distribution networks.
 - For some small truckers with limited operating range, there may be only one route available. These operators may simply have to “wait it out.”

Events that trigger the execution of a resiliency plan are tied to product inventory requirements from the shipper point of view. Considerations like the type of commodity, stock on hand, lead times, and product demand influence when resiliency plans are

¹⁰ A stock-out is a situation where the demand or requirement for an item cannot be fulfilled from the current (on hand) inventory.

¹¹ Safety stock is inventory held as buffer against mismatch between forecasted and actual consumption or demand, between expected and actual delivery time, and unforeseen emergencies. Also called reserve inventory.



implemented. Interruptions lasting a few days may not warrant any action if inventory on-hand can absorb the delay of deliveries or if truckers can drive around blocked areas without having to initiate the formal resiliency plan. Freight traffic can be expected to steadily grow over time, as inventories decline, and resiliency plans become activated.

Shippers generally make the decision to source freight from an alternate location, while transportation carriers appear to be relatively passive in the decision-making process. Depending on the length of transit for an alternative product source, shippers consider alternative modes, like rail in place of truck for blockage durations lasting a month or more. The choice of rail over truck would depend on the additional distance of the alternative source, the lead-time requirement of the cargo and the availability of rail service. The total rail transit, including dwell time in the origin and destination rail yards would have to be within a few hours of the re-routed truck transit time.

It is important to recognize that the timing of the resiliency plan execution can impact its effectiveness, due to the likely competition for limited resources, such as fuel, trucks, trains, and warehouses.

The volume of freight flowing in an area can also be impacted by the type of event. A hurricane that affects a wide area will effect discretionary product consumption, and will therefore reduce the amount of cargo flowing into the affected area. The most extreme example of this was New Orleans, LA during the aftermath of Hurricane Katrina, where a large portion of the population left the city, either never to return or returning months later. In contrast, interruptions isolated to port or rail services for example, are not likely to reduce product demand, and therefore freight volume, because the population in general and product consumption, is not substantially impacted.

Surface Transportation Service Providers

According to interviewees, cargo shippers set high level resiliency plan objectives and look to their transportation service providers to meet those objectives.

Truck

Over-the-road carriers are more likely to have a tactical response to extended disruptions, as one interviewee noted, "There are too many variables in play." The initial response to a service interruption is the rapid reaction to changing conditions during the first hours or days of a disruption. During this time, truck carriers depend on their dispatchers and drivers to relay information about real-time conditions and to choose routes based on known options. Then, as the freight transportation network stabilizes, the trucker can begin to make longer term routing decisions based on stabilized information about network alternatives, alternative sourcing, and cargo demand requirements. By this time, trucking companies are generally responding to shipper requests for pick up and deliveries based on the need for products.

Tactical response by truckers considers the following:

- Safety is the first priority, both for drivers and for cargo.

- Identify surface road work-around based on knowledge of local routes
 - Some truckers have aids, such as PC Miler Routing Software, that suggest alternative routes and estimated transit times.
 - Dispatchers, other truckers, and on-board GPS devices are key resources for finding alternative routing.
- Maintain operational continuity throughout the disruption by identifying alternative facilities, including:
 - Dispatch centers if existing facilities are off-line. The loss of communications during an event effectively disables the trucking company.
 - Truck terminals where stranded cargo and drivers can park and wait or drop cargo if delivery or pick-up of goods is not possible.
 - Terminals should include truck repair according to one interviewee.
 - Secure storage areas are important, especially if looting is a possibility.

Routes of Key Concern

In light of the perception that resiliency plans react to conditions as they occur, interviewees only mentioned the main highways in Texas as areas of concern, for the obvious reason that these thoroughfares carry the most traffic within Texas. Highways connecting main Texas cities or crossing the Mexican and adjacent US State borders were cited. Figure 1 displays the interstate and US highways in Texas.

Alternative Routing Decisions

Using information provided by truck drivers and dispatchers, any alternative route used will likely have the following characteristics:

- Shortest transit time of all other options
- Safe for trucks
- Parallel highway or road to the affected road
- Low congestion level, even if second or third route choice

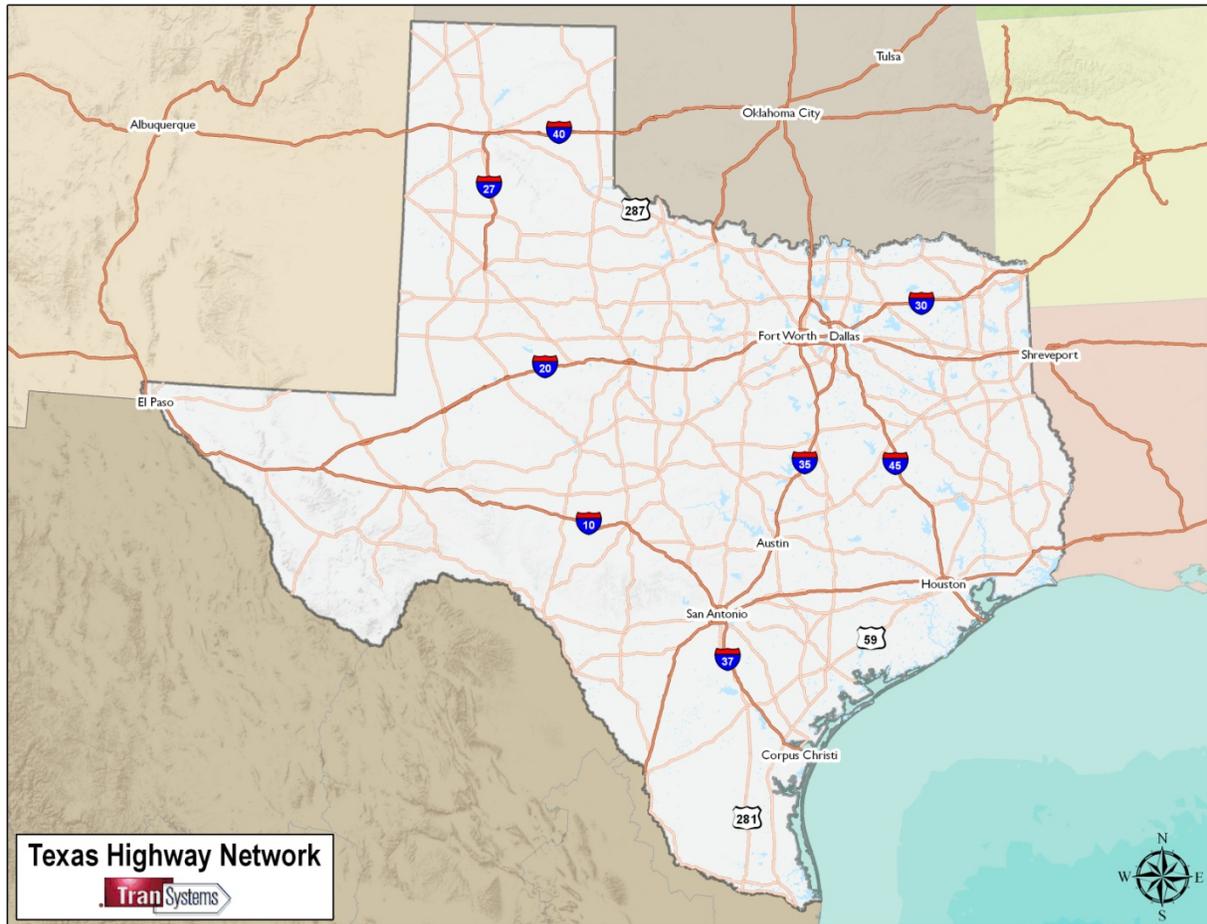


Figure 1. Key Texas Highways

Source: TranSystems.

Initial detour choices may be sporadic, as various options are explored including nights, weekends, and alternative hours. Over time, alternative route traffic patterns should stabilize as trucking companies and shippers settle on routing adjustments.

Direction of Traffic

As observed in weather-related natural disasters, the initial traffic flow will be outbound from an affected area, and inbound traffic gradually increases as the demand for freight returns. Based on input from shipper interviews, the source and direction of freight traffic will also likely shift if warehouses or port access is blocked in one region but is available in others. A grocery shipper interviewee suggested that if his cargo distribution center (DC) in Dallas were to be damaged, he would immediately begin sourcing from his DC in Florida to re-stock his stores in Texas. In this case, outbound cargo from Dallas would decline on IH 35, IH 10, IH 45, and inbound freight into Texas would increase on IH 10, IH 20 and IH30. Similarly, if the Port of Houston became inaccessible for a number of weeks, shippers might consider unloading cargo at the Port of Los Angeles, CA, and rail or trucking cargo eastbound to Texas locations.

Alternative sourcing caused by port disruptions is discussed further in the Waterborne Transportation of this report.

Figure 2 illustrates an alternative routing example for cargo destined for Dallas, diverted from a long-term DC closure in Houston to DC locations in Florida and Kansas:

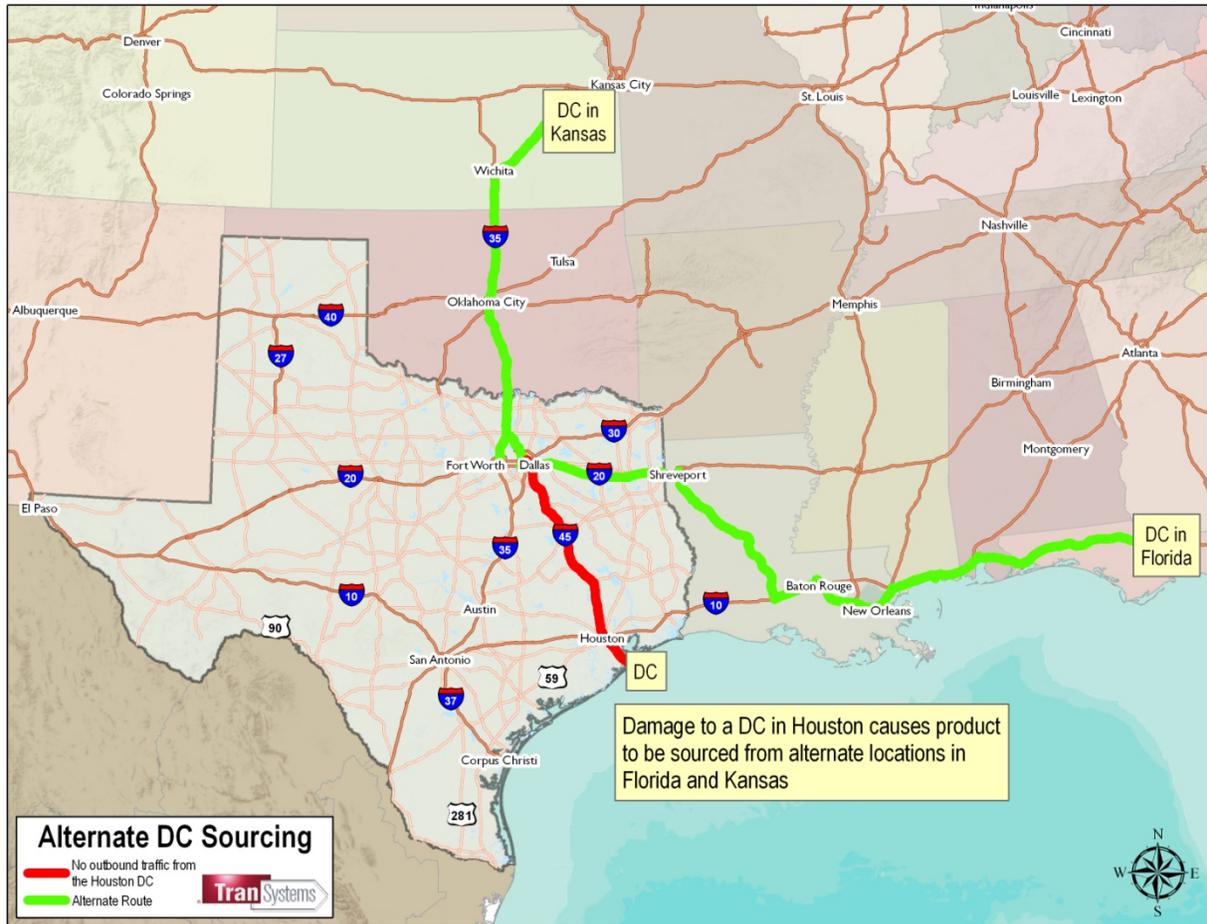


Figure 2. Alternate Distribution Center Sourcing

Source: TranSystems.

Freight traffic that would normally transit IH 45 northbound is diverted to IH 20 westbound and IH 35 southbound. Figure 2 demonstrates that re-routed cargo may come from the opposite direction of a blocked route or transportation facility.

Interviewee Suggestions

TxDOT was viewed as having a support role, mainly focusing on communication. Timely and easily accessible information that assists truckers with routing around blockages was the most common request. The following suggestions regarding potential assistance from TxDOT are as follows:

- Communicate alternative routes and provide estimated transit times.
- Establish commercial routes.

- Establish toll roads on key routes to deter unnecessary traffic, assuming that free routes exist.

Rail

Interview responses suggest that railroads have extensive experience with addressing service disruptions within the course of providing every-day rail service. Responding to rail service disruptions caused by train derailments, weather-related events that damage tracks and bridges or long-term maintenance projects are a crucial component of maintaining reliable rail service. As such, resiliency planning is considered to be an integral component of daily operations. Similarly, public and railroad personnel safety are the key considerations both in every day operations and in freight resiliency planning. Railroads have a well-coordinated response to service interruptions because they are the managing organization(s) for the rail network.

A railroad's approach to a resiliency event depends on the amount of preparation time that is available. A hurricane, for example provides enough lead time to institute a system shut down that involves the removal of rail assets, such as rail cars and locomotives, from areas that are expected to experience damage. Additionally, personnel and supplies needed to bring the rail system back online are prepositioned to ensure a rapid recovery. Generators are included in the prepositioning process to power rail communications systems, signals, and warning devices at highway-rail at-grade crossings in case of a power outage. Flag-men will be posted at highway-rail at-grade crossings where power remains unavailable.

After the disruption occurs, railroads move to a recovery approach. Tracks, bridges, and at-grade highway-rail crossings are inspected to confirm that safe operations can resume. If track repair is necessary, priority is given to tracks that can be repaired quickly. Long-term network outages are then handled by rail operations to identify new service routes.

Alternative Routing Decisions

The rerouting decision depends on the length of the outage. Trains may hold in place if a disruption lasts for a day or two because the time to detour the train could equal the length of the disruption. Rail outages of longer than a few days will require trains to be rerouted. Once the source of the outage is identified, a process flow is initiated that traces the network backwards until a passable route is established. The scope and severity of an outage dictates the backtrack distance needed to reroute the train. Trains that have the clearest and easiest path to their final destinations are rerouted first, and others that are most negatively affected by an outage, either by a severed connection or that require extensive rerouting are moved last. This methodology clears congestion as quickly as possible. An additional consideration when prioritizing track repair is the demand for rail service. This was highlighted recently by a prolonged closure at the Port of Galveston caused by Hurricane Ike. The timing of track repair needed to access the port was delayed to coincide with the resumption of port operations that required rail service. In addition, railcars were positioned to alternative ports to handle cargo that was scheduled to be handled at Galveston.



Railroads also have reciprocating track rights agreements. The Union Pacific (UP) railroad recently experienced a landslide that closed a portion of its tracks for 90 days. The BNSF Railway allowed the UP to use its line while the UP section was repaired. In some cases, these agreements allow for a redundant rail network capable of responding to disruptions of virtually any duration.

Cargo Conversion to or from Rail

A complete blockage of rail service in Texas is extremely unlikely. Small areas could conceivably become inaccessible for extended periods of time due to severe track damage. The result would be increased truck traffic between the first available rail access point and points beyond the rail outage.

Truck traffic converting to rail depends on the additional transit time added as a result of the disruption. Shippers may convert from the truck to the rail mode if the total rail transit is within a few hours of the rerouted truck transit time. Any mode shift to truck would put additional stress on the local transportation network surrounding terminals that may not be designed to handle the additional load.

Interviewee Suggestions

- Railroads rely on electricity to ensure safety, as well as to operate communication, signal, and highway-rail at-grade crossing systems. As part of emergency coordination, utility companies should be made aware of this need and give railroad companies priority when maintaining and restoring power.
- Continue the good relations with local law enforcement that allow emergency rail crews to access tracks when public roads are closed.

Waterborne Transportation Facilities and Providers

Ports and Terminals

Ports and Terminals do not ordinarily dictate the amount of cargo heading inbound or outbound from their gates. Those decisions are left to the ocean carriers that manage the relationships with the cargo shippers, and port terminal operators have little impact on making decisions that affect traffic. As a result, port and terminal resiliency plans focus on the safety of personnel and implementing procedures that are designed to bring systems back on-line in a safe and effective manner. In Houston, for example, the Port Consolidation Team has a post incident checklist of the utilities and services required to bring all port facilities and terminals back online. Individual terminals have similar procedures that are specific to their facility. The water channel itself falls under the jurisdiction of the US Coast Guard (USCG) with assistance from the USACE, which has the responsibility to ensure that the channel is clear and has the sole authority to close or open the port. As information, one interviewee noted that a closure at the Port of Houston is estimated to cost \$334 million per day, which emphasizes the importance of a fast response to service disruption.

There is no umbrella agency coordinating communications between the terminals, truck lines, and railroads; however, the Houston Port Authority does perform outreach to



truckers, freight forwarders and other transportation providers to respond to inquiries about the status of port closures.

Alternative Routing Decisions

According to interviews with port and terminal personnel, The Port of Houston handles a disproportionately large number of trucks as compared to other large US ports, using IH 45 as the main access highway. The effect of a blockage to the port would cause a reduction of truck traffic on IH 45 to the IH 10 junction, and a likely increase in traffic inbound from Louisiana on IH 10 and IH 20, as shippers begin alternative sourcing strategies to replace cargo previously originating at the port.

Interviewee Suggestions:

The port and terminal operators that were interviewed were hard pressed to offer recommendation of how TxDOT can support their resiliency plans. One interviewee noted, however, that all mission critical personnel required to bring a terminal back on-line should be given an identification card that would allow them to pass through roadblocks or road closures during the terminal start-up phase. Not all of these mission critical employees have the necessary identification to get to the terminal if necessary.

Barge Transportation

The primary concern for barge operators is the safe operation of barge tows, which includes consideration for tug crews, other vessels, cargo, and the safe navigation of barges through waterways. Barge towing companies also comply with vessel security plans that address prevention and response to a terrorist attack, pursuant to the Marine Securities Act of 2002.

The most common and likely event that would cause a prolonged blockage to a waterway is a hurricane, according to the barge operator interviews. Weather-related disruptions provide some lead-time to prepare for a potential disruption, such as positioning tugs and barges to safe locations. Other incidents that do not provide advanced warning, such as vessel collisions that block channels, require a more reactive response to restore barge service.

Alternative Routing Decisions

Barges choose the quickest, safest alternative route in response to a waterway blockage. Alternative courses are chosen based on routes that are clear of obstruction and are capable of handling the size and draft requirements of a tow. The large network of rivers and their tributaries in the US present many alternatives, but choosing the fastest and safest routes depends on reliable information regarding the navigable status of inland waterways. Similar to the trucking mode, tugboat crews and barge dispatchers are the best source of real-time waterway conditions, along with the USCG and the US Army Corps of Engineers.

In situations where an optional waterway is not possible, the most likely alternative transportation mode would be rail because this mode is capable of accepting large shipment sizes normally handled by barge. Pipelines may also be a resources for transporting some commodities.



Routes of Key Concern

The Gulf Intracoastal Waterway (GIWW) between Houston and Port Arthur has no other inland waterway option and cargoes relying on this channel would need to convert to another mode of transportation if it became unavailable. The GIWW is also vulnerable, due to its narrow channels, and single lock design; serious damage to a single lock would cause considerable delays.

Interview Suggestions

Barge services can be used for emergency response. The tugboat company interviewee suggested that barges can be an important component in a response to a catastrophic incident, especially if other modes become unavailable.

A container on barge service might assist in emergency situations to distribute cargo if railroad and truck services are not available. Containerized cargo unitizes large volumes of cargo, thereby allowing for the expedited distribution of cargo, as containers can be immediately loaded onto trucks, bypassing interim warehousing and re-loading steps.

In the aftermath of Hurricane Katrina for example, barge capacity was available, and had access to New Orleans within two or three days, while truck and rail routes remained disabled. "We could have brought in containers of bottled water within a few hundred yards of the Super Dome" rather than airlifting relief cargo in at a considerably higher price, noted one interviewee.

Other uses of barge services include assistance to ocean terminals with container repositioning or evacuation. Barge is also a viable alternative to rail, considering this mode's access to other ocean ports, and its ability to move cargo well inland via the Mississippi and other major US rivers, to access major cities and railroad hubs.

Ocean Carriers

Similar to other transportation modes, Ocean carriers consider safety of personnel, vessels, and cargo in that order; however, specific actions taken to respond to service disruptions may not necessarily be considered to be part of a formalized resiliency plan. Following procedures to bring facilities back online and releasing cargoes in accordance with shipper needs are their main concerns.

Impact on Truck Traffic

Considerations that affect truck traffic in Texas center on cargoes that have been unloaded at terminals at various Texas ports and await delivery. Ocean carriers' customer inventory re-stocking needs drive how much, and which cargoes are released first. Increased congestion can be expected as terminals resume operations, as vessel backlogs are gradually worked away.

Inbound cargo congestion can be managed somewhat by the ocean carriers, as export bookings can be canceled if congestion at the terminal is too severe.

Choosing an Alternative Port

Longer duration disruptions of two or more weeks may cause a decision to unload cargoes at an alternate port. For larger ocean carriers that have set service schedules and networks, the decision to change a vessel itinerary is heavily weighed because service times have to be evaluated for the entire global network. Depending on the expected duration of an event, ocean carriers have three unloading options:

- An alternative port may be chosen.
- The ships may wait at anchor until the port opens. Vessels laid at anchor for four or five days after Hurricane Ike, for example, rather than diverting to other ports.
- Vessels may bypass the Port of Houston and continue on their US inbound port rotation. The decision to return to Houston on the outbound voyage would depend on the status of the unloading terminal in Houston.

Even smaller carriers have pre-arranged where cargoes are to be unloaded and simply calling another port is an expensive and time consuming proposition.

If the decision is made to call at a different port due to an extended port closure, traffic can be expected to flow into Texas from routes connected to those ports. Cargo from South America for example may be diverted to Jacksonville, FL, and enter Texas via IH 10. Houston-bound freight transiting the Panama Canal may divert to US West Coast ports, where it might be railed or trucked to Texas.

Texas State Fuel Team

A good example of a Public/Private partnership that manages major traffic disruptions during natural disasters is the Texas State Fuel Team. The Fuel Team incorporates the necessary components of resiliency planning based on a clear understanding of the demand for its product and distribution challenges that a natural disaster present. Communications, pre-planning, and actions to be taken during an event are clearly established.

After Hurricane Rita in 2005, Texas Governor Perry created the Task Force on Evacuation, Transportation and Logistics to address problems encountered during and after Hurricane Rita. The Task Force recommended the formation of a State Fuel Team to be part of the State Emergency Management Plan. Although not part of any state agency, the Fuel Team works closely with the State Operations Center to provide information about fuel supply, demand, and projected needs in the event of an evacuation.

The Fuel Team, comprised of representatives of not-for-profit trade associations, makes sure Texas has a reliable fuel supply along evacuation routes and helps in recovering the fuel network as quickly as possible post-storm. The Team uses its networks to notify industry segments to replenish fuel supply to be ready for increased demand as residents fill up for a potential evacuation. The Fuel Team communicates with the entire fuel supply chain, including production and storage, crude oil storage, pipelines, ports, tankers, barges, truckers, retail storage facilities, and gas stations. Before



evacuation is ordered, the Fuel Team monitors traffic and fuel demand to prioritize fuel deliveries to the areas most in need.

The Fuel Team is a private sector partner with the State and serves as a communications hub for fuel availability and demand within the State Operations Center during storm activities. Regular updates along the entire fuel supply chain are provided to the Fuel Team, which coordinates information received from multiple public and private sector sources. One outcome of this is increased deliveries of fuel in higher demand areas and to critical facilities, such as hospitals, as directed by The Fuel Team.

Pre-planning includes communications drills prior to the hurricane season. Planning includes the identification of the personnel and vehicles needed to quickly respond to critical fuel recovery needs, and to ensure that waivers, permits, other necessary elements are in place to ensure a rapid response.

The assistance of several government agencies, such as Texas Department of Public Safety and US Department of Homeland Security (DHS) are essential to the re-entry of an area that has been damaged by a storm. TxDOT provided real time information about road closures, conditions, and traffic that was used to identify alternative routing of fuel during Hurricane Ike. Port conditions and availability were also monitored to ensure crude deliveries, also with the help of DHS and USCG.

Conclusions and Recommendations

The combined plans of shippers and transportation providers establish the strategic and tactical components of private-sector resiliency plans. Shipper plans focus on replenishing and maintaining inventory levels for products throughout the duration of a disruption, while the transportation providers focus on delivering products per the shippers' instructions. Many of the companies interviewed have response plans designed to re-route cargo in emergency situations; however, they may not be contained in a formal resiliency plan.

When a resiliency event occurs, private sector shippers and transportation providers generally focus on clearing freight in the immediate aftermath of the event. As the situation begins to stabilize, they establish plans to recover from the incident by identifying the appropriate products and route alternatives that will meet inventory level and lead time demands. This may result in traffic coming from unexpected directions, as freight begins to flow from alternative sources to compensate for facilities or routes that are unavailable.

Communication is the fundamental component of a resiliency plan. Transportation personnel, such as truck drivers, barge tow captains, and dispatchers are heavily relied upon to provide information that is critical to finding and establishing alternative routes. Understanding and knowing all alternatives, including those provided by transportation personnel would be useful; however, interviewees were not aware of any umbrella communication channel that provided inclusive information about the status of all



transportation modal options that might affect freight flows. The exception to this is the communications process established by the Texas Fuel Team.

TxDOT was viewed as having a support role in assisting the private sector to recover from man-made or natural freight resiliency events. Communication was overwhelmingly the primary need expressed.

- Providing up-to-date status reports on the estimated blockage duration.
- Suggest alternative routes.
- Estimate transit time of routes.

Assisting carriers with traffic direction was also mentioned:

- Designate freight corridors.
- Establish emergency toll roads, assuming toll free passage routes are also available.

In light of interviewee comments noting the lack of a central location for all transportation-related activities during a severe disruption, TxDOT might consider creating a tool that assists shippers and transportation providers when considering various options. A single location providing information on such things like traffic conditions, barge and rail availability, port status, and emergency truck stop information is recommended. Communications processes used by the Texas Fuel Team may be a good emergency communications benchmark.

Interview Respondents

Most Companies who participated in the Texas Statewide Freight Resiliency Plan Private Sector Interviews wished to respond anonymously, in accordance with company policy. Companies that might be identified by revealing their location show "Operating in TX" under the location column.

Company	Location	Industry
Kirby Marine	Houston, TX	Barge Transportation
Confidential	Operating in TX	International Ocean Carrier
Confidential	Operating in the Gulf	Barge Transportation
Texas Oil and Gas Association	Austin, TX	Energy Industry Association
Confidential	Dallas, TX	Third Party Logistics Provider (3PL)
Confidential	Dallas, TX	Trucking Industry Association
Confidential	Corpus Christi	Trucking Industry Association
Confidential	Operating in TX	Regional Truckload Carrier
Confidential	Operating in TX	General Freight Local Trucker
Confidential	Operating in TX	General Freight Local Trucker
Confidential	San Antonio, TX	Oilfield Services Trucker
Confidential	Operating in TX	Ocean Terminal Operator
Confidential	Operating in TX	Class 1 Railroad Company
Confidential	Operating in TX	Port Authority
Confidential	Operating in TX	Rail District
Confidential	Operating in TX	Regional Railroad Company



Confidential	Operating in TX	Grocery Retailer
Confidential	Houston, TX	Third Party Logistics Provider (3PL)
Confidential	Dallas, TX	National Retail
Confidential	Operating in TX	Ocean Carrier
Confidential	Operating in TX	Computer Manufacturer

Source: TranSystems.



Appendix C: Maritime Assessment Case Study



Introduction

The Texas Department of Transportation (TxDOT) recognizes that the highway system is a major component of a resilient freight network. As the managing organization responsible for maintaining the State's highways and the Gulf Intracoastal Waterway, TxDOT is developing a Statewide Freight Resiliency (SFR) Plan to provide a comprehensive framework for identifying key freight infrastructure corridors and develop strategies to ensure a resilient freight transportation network in the State of Texas.

A part of developing the SFR Plan, TranSystems interviewed terminal operators, ocean carriers, US Coast Guard, and members of the Houston Port Coordination Team to gather information on events that caused recent port disruptions. The purpose of this case study is to illustrate how vessel and road traffic conditions are impacted based on an actual, unplanned interruption of waterborne traffic at the Port of Houston. In addition, TranSystems obtained vessel movement data from the Greater Houston Port Bureau, and traffic drive time data from Houston TranStar to measure traffic conditions.

Truck traffic resulting from container vessels is a critical factor affecting traffic in the port, and is therefore the focus of this study. The study area is centered around Barbours Cut and Bayport container terminals, which are the area's key container terminals, including their main access highways, SH 146 and SH 225.

Container Ship Terminal Operations

Container ships carry boxes, or containers, that are commonly forty feet in length and 8.5 feet high. These containers are attached directly to chassis for over the road transit, or removed from chassis and stacked onto ships for ocean transit. A single container vessel can load or unload 2,000 or more containers in a day at the Port of Houston, with each container resulting in an over-the-road truck trip or drayage.

Case Study Event Selection

Private sectors interviews completed for the Texas SFR Plan suggest that, while hurricanes are the most likely cause of extended port disruptions, transportation companies have some advanced warning of these events, and have informal action plans at minimum to address resulting closures. TranSystems identified port incidents that provided little or no warning, including the October 2010 barge collision with a power line tower. This incident closed a portion of the ship channel for three days; however, container ship traffic was not impacted.

Discussions with Port of Houston and terminal personnel indicated that an event that resulted in a period of intermittent port closures occurred in December 2007, where fog severely disrupted ship traffic over seven days. This was considered to be the most recent example of a situation that caused port operators and ocean carriers to consider alternative operating plans. Fog is common for the Houston area in the months

of December and January; however, the December 2007 fog event caused substantially more port closures than was usual according to interviews.

December 2007 Fog Disruption

The Houston ship channel is maintained at a depth of 45 feet, and a width of 530 feet. It is not uncommon for ships with a beam (width) of 150 feet or more to pass in opposite directions, leaving a margin of 230 feet to navigate between the channel edge, and oncoming vessels. Figure 1 illustrates two vessels passing, each with a beam of 131 feet. Even under fair conditions, a high degree of navigational skill is required to transit the Houston Ship Channel. Figure 2 illustrates hazardous conditions caused by fog in the Houston Ship Channel.



Figure 1. Containerships Passing in the Port of Houston Ship Channel

Photo used by permission: "Before", Lou Vest, Houston Pilots Association, September 2006.



Figure 2. Tankers in the Houston Ship Channel in Fog

Photo used by permission: "Fog in Tight Places", Lou Vest, Houston Pilots Association, March 2007

For a period of seven days in December 2007, heavy fog caused The Port of Houston's Port Coordination Team to intermittently restrict vessel movements within the port due to extreme low visibility. Highest priority was given to vessels serving terminals with the greatest need, which tended to be tanker vessels serving oil refineries.

Houston port refineries produce roughly eight percent of the nation's petroleum fuel supply, according to a representative of the Port Coordination Team. Refineries keep several days of crude inventory on-hand, and can withstand an oil supply interruption of a few days; however, when inventories run low, overall fuel supply to the US is threatened.¹²

Waterside Impacts

Container ships were allowed in and out of the port considering the urgency of their cargo relative to the demand for crude oil deliveries. Container ships experienced severe delays during this time, both entering and exiting the port. Figure 3 displays the

¹² The October 2010 barge incident cut off tanker access to the refineries for three days, but did not substantially impact refinery operations due to stored terminal inventory.



number of container ship arrivals, and port duration days, by date. The blue bars represent the number of ships that arrived each day, as measured by the left vertical axis. Red outlined bars indicate the number of days these same ships remained in port, and are measured on the right vertical axis.

The Port of Houston was closed on Christmas Day, when vessel load and unload operations were not performed. No container ships arrived in port on December 7, 9, and 21, 2007, and January 5 and 14, 2008.

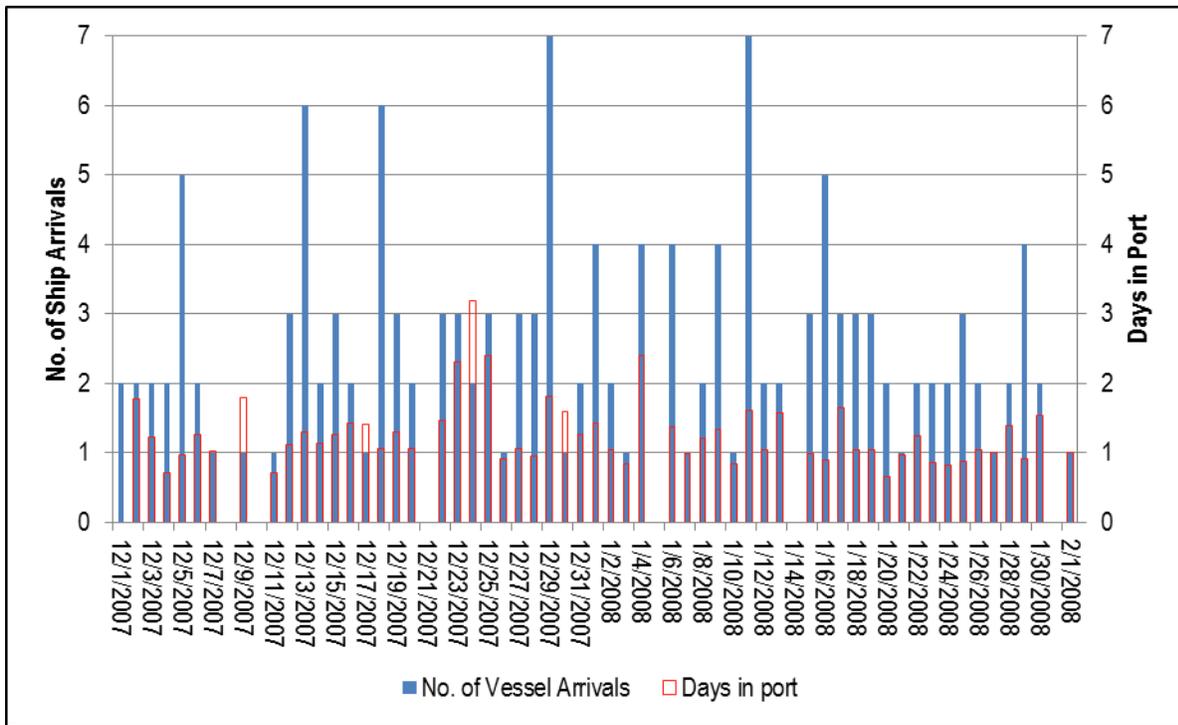


Figure 3. December 2007 - January 2008 Port of Houston Container Vessel Arrivals and Port Duration Source: Greater Houston Port Bureau and TranSystems.

In January 2008, which was not as drastically impacted by fog as December 2007, the average port duration of a container ship was 1.16 days, or 27 hours. This length of stay provides a point of reference for comparison purposes, and interviews confirm that this dock-side duration is about average for container ships at the Port of Houston. As indicated in Figure 3, one four day stretch, from December 22 to December 25, 2007, accounted for three out of four days where vessels averaged more than 2 days in port. The reason for these extended port stays was attributed to fog. The Port of Houston was closed to loading and unloading operations on December 25, but this was not a reason for extended stays, because of the additional “dockage charge¹³” for extra days in port. Ships wait at anchor in these situations to avoid higher shore-side costs. Other peak port stay days generally proceeded a day when container vessels were not allowed to move, and averaged between 1.5 to over 2 days in port. December 9, 2007, January 4, 14, and 30, 2008 preceded fog restriction days. Additionally, days when a total of seven ships were in port also experienced higher than average vessel port stays, averaging about 1.75 days.

Interviews with ocean carriers and terminal operators reveal that vessel safety is the primary concern, but vessel itinerary integrity, customer demand for cargo on the vessels, and empty container availability for export customers are also key

¹³ Dockage is a cost charged to vessels for staying at a berth.



considerations. In reaction to the December 2007 port restrictions, ocean carriers and terminal interviews offered the following observations:

- Ocean carriers are committed to meeting established vessel itineraries, and an extended period of uncertain port access is of concern. A disruption lasting a week or more causes ocean carriers to consider various contingencies. In this case, vessel traffic was heavily restricted; however, there was the daily possibility of ship movement. Ocean carriers waited at anchor because any alternative port was too far away, and a detour would introduce too much additional time to the schedule.
- According to interviews, terminal congestion was not an issue given ample capacity at the Port of Houston. Additionally, in 2007, the new Bayport terminal had recently opened, and had excess capacity. Even today, respondents indicate that the existing terminal capacity can handle a week long disruption of vessel access due to available capacity, and efficient container storage practices.
- The biggest problem facing terminal operators during this time period was managing customer requests to pickup cargo that was delayed onboard vessels awaiting entry into port. This situation relied on terminal communications to shippers, advising them not to send trucks until the ships arrived. Truck traffic actually decreased as a result of these communications. Higher truck traffic ensued after delayed vessels were allowed to enter the port.
- The Port of Houston containerized trade balance is 65 percent export and 35 percent import. The challenge for terminals in an extended disruption can be mitigated by advising export shippers not to deliver containers to the ports if terminals exceed capacity levels.
- Empty container availability needed for export cargo would become limited if the Port of Houston were closed for an extended period. As stated, 35 percent of the Port of Houston volume is import cargo, which provides an insufficient source of empty containers to meet the 65 percent export cargo demand. Empty containers are brought in on vessels to meet the need for empty export containers. In December 2007, empty container availability was not an issue, but would have been if the disruption lasted longer than a week.

In short, ocean carriers and terminal operators who were interviewed suggest that the December 2007 disruptions caused by fog did cause changes to vessel load and discharge scheduling, but the week-long delays were insufficient to initiate major changes to vessel itineraries. All respondents suggested that any event lasting less than a week was not likely to cause substantial adjustments to operating plans. Two interviewees offered that the Port of Houston was closed for only four days even after a major event such as Hurricane Ike, which caused major local damage in Houston and surrounding areas, suggesting that the Port of Houston demonstrated resiliency even under severe circumstances.

Landside Impacts

State Highways 146 and 225 are the main highway access points to Port of Houston terminals. Interviews suggest that waterside disruptions at the Port would likely have little impact on highway traffic given that terminals can absorb export containers delivered over one week, and import containers would be prevented from entering the port. Substantial truck traffic increases might be expected the day of, or the day after a vessel arrives in port, especially if vessel arrivals have been delayed. Two terminal operators; however, indicated that SH 146 and SH 225 are generally uncongested, and even truck traffic generated by working six or seven ships simultaneously does not create noticeable increases in highway traffic congestion in the Port area.

To assess the impact of altered vessel arrivals on traffic patterns, TranSystems analyzed traffic speed data provided by Houston TranStar, by correlating vessel arrivals and measurable traffic delays on highways near to the Bayport and Barbours Cut terminals, e.g. SH 146 and SH 225. TranSystems did not find a relationship between reduced traffic speeds and vessel arrivals, vessel days in port, number of vessels in port, or port closure days, including lagging effects of port closures. Figures 4 and 5 plot average miles per hour, by date and hour for selected portions of SH 146 and SH 225 that indicated slower than average speeds during December 2007. These highways could have received higher than normal truck traffic due to the adjusted arrivals and departures of ocean carriers. Red dashes indicate times when reduced speeds would have been expected due to late vessel arrivals, yet the charts show that slower traffic did not occur:

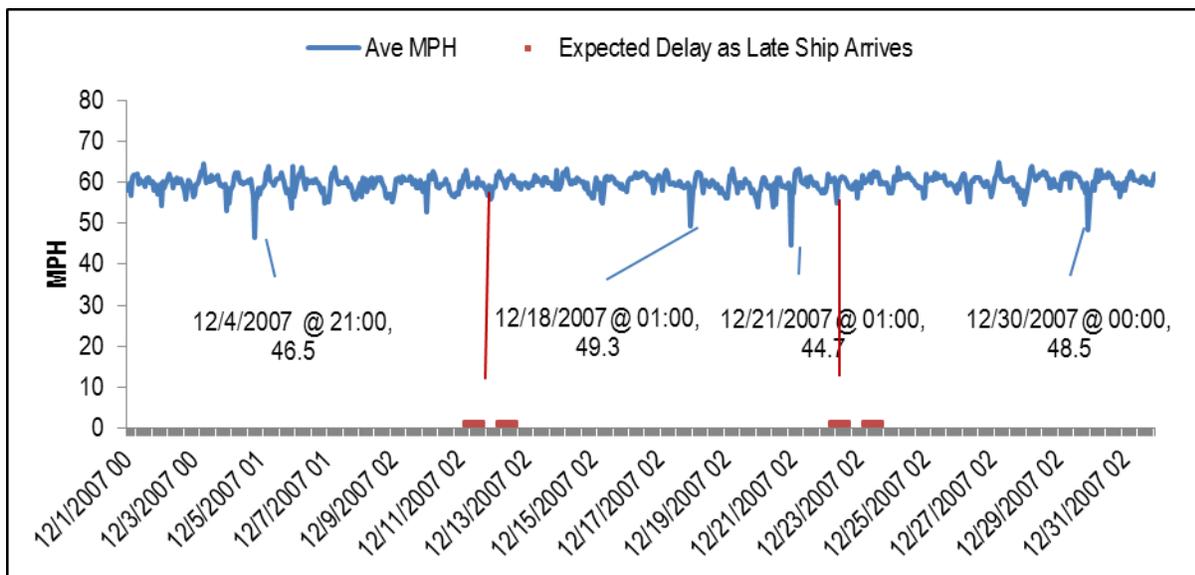


Figure 4. Average MPH December 2007 - SH 146 SB, North of the Fred Hartman Bridge

Source: Houston TranStar and TranSystems.

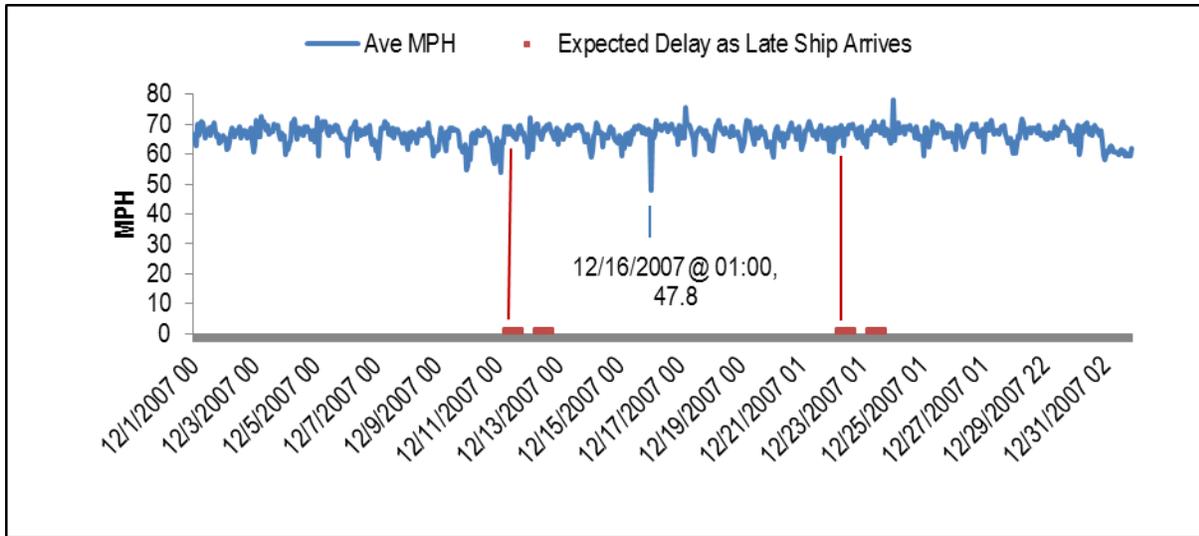


Figure 5. Average MPH December 2007 - SH 146 SB, South of the Fred Hartman Bridge to Barbours Cut

Source: Houston TranStar and TranSystems.

Traffic speeds for these highways generally flowed at speeds in excess of sixty miles per hour. Speeds averaging below fifty miles per hour, for purposes of this study, are considered to be substantially lower than the normal travel speeds of the Bayport and Barbours Cut area freeways. Only five occasions occurred where the average speed fell below 50 mph, as displayed in Table 1.

Table 1: December 2007 Traffic Speeds under 50 MPH Summary		
Location	Date and Time	MPH
SH 146 SB, North of the Fred Hartman Bridge	12/04/07 @ 21:00	46.5
SH 146 SB, South of the Fred Hartman Bridge to Barbours Cut	12/16/07 @ 01:00	47.9
SH 146 SB, North of the Fred Hartman Bridge	12/18/07 @ 01:00	49.3
SH 146 SB, North of the Fred Hartman Bridge	12/21/07 @ 01:00	44.7
SH 146 SB, North of the Fred Hartman Bridge	12/30/07 @ 00:00	48.5

Source: TranSystems.

Four out of five traffic slow-downs occurred between the hours of 00:00 and 01:00 in the morning, when the ocean terminals were not open. The other slow incident occurred at 9 PM on December 4, again when ocean terminals were closed. Traffic speed data do not indicate that ship delays due to the closures of the Port of Houston had any impact on traffic around the port.



Conclusion

Traffic speed data confirm the findings of interviews with terminal and ocean carrier personnel, that the vessel delays caused by fog in December 2007 did not have a substantial impact on traffic in the area. Slower traffic did not materialize in conditions where higher truck volume was expected, specifically during the days immediately following delayed vessels' port arrivals.

According to respondents, disruptions lasting longer than a week may cause ships to bypass the Port of Houston; however, shorter duration disruptions are not likely to initiate such a plan. While ships were allowed through intermittently during the time frame of this case study, respondents suggest that terminals are able to handle a week's worth of cargo even if the Port of Houston experienced a complete shutdown for an entire week, without drastically impacting highway traffic.



Appendix D: Maps

