

Texas Department of Transportation

Implementing Freight Fluidity for Texas and Its Regions

A Guidebook

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Table of Contents

What is Freight Fluidity?

Freight Fluidity is measuring trip performance to determine how efficiently goods are moving in a region. It involves answering questions like: What are the goods? How do they get from point A to point B? What's the route?

1. Introduction

1.1 What Is This Guidebook? How Will It Help?

This is a guidebook written for you (transportation planners, policy makers, and system operators) to help in understanding what freight fluidity is and to illustrate the importance of the information freight fluidity provides. The goal of this guidebook is to compel you as a decision maker to want to know about freight fluidity and use it in your daily work. It should help you to easily use fluidity analytics and information to support the investment and operational decisions that you need to make.

Freight Fluidity analytics include the following types of analyses:

Awareness of **goods moving in the region.**	Understanding of **current economic conditions and supply chain opportunities.**	Use of awareness and economic/supply chain intel to identify **key trip routes for freight.**	Assessment of **freight mobility and bottlenecks along these trip routes.**

Depending on your role and the questions you wish to answer, you may be interested in all these analyses or parts of them. Performing the totality of analyses will provide the most in-depth information on freight trip performance that you can use in your role for planning or programming transportation improvements. However, each individual analysis can provide excellent insight for freight that will be value added for the work that you do.

1.2 What Is Freight Fluidity? Why Care about It?

If you are reading this guide, you are likely a transportation decision maker. Maybe you are a planner or district operator/engineer at the Texas Department of Transportation (TxDOT), or perhaps you are with a metropolitan planning organization (MPO). You might be a leader or key decision maker, or maybe you represent a local government.

Whatever your role, you are likely a person who needs to know how well things are moving on the transportation network, and you have some role in deciding or planning what to do to improve the network. This may be through capital projects, or it could be policies, operations, and new Transportation Systems Management and Operations (TSMO) approaches.

In terms of how well things are moving, you are interested in how people and goods get from place to place on your network or throughout your state, region, or even internationally.

Simply put, freight fluidity is measuring trip performance to determine how efficiently goods are moving in a region. It involves answering questions like: What are the goods? How do they get from point A to point B? What's the route? It is understanding the goods that are critical, the trips they make, the systems they use, and then how well they are moving. If you liken freight fluidity to a trip you might make for a vacation, you could think of it this way:

You start your trip from your house. You drive to the airport, get to the airport and go through security, board your plane, and fly to another place. Once there, you wait for your bags. Then, you take a taxi to your hotel. Along that trip, some parts of it took longer than others. Maybe your plane was delayed. Perhaps you were stuck in traffic on the way. Thinking about your trip, which parts of it were the slowest? Where were your bottlenecks? What could be improved to make the trip faster and more efficient from point A to point B?

Now think about the trips that goods make—from the factory to the store shelf, from the farmer to the grocery store, from the oilfield to the refinery. Goods will take multiple links, just as you might on vacation. They may travel by ship to rail to truck or some other combination of modes. There will be points along that trip that are bottlenecks, while others are smooth.

When you get delayed on your trip, you pay a personal cost of time. You may even have to pay fees or additional costs for tickets or trip changes. There are costs associated with the bottlenecks you experience along the way, either to you or to the travel company or airline, for example.

When goods get delayed, there is a similar cost. This cost of delay adds to the overall price of the good. This means that in places with many bottlenecks, the cost of goods can be higher and then drive up the cost of doing business. There may likewise be an impact on jobs.

For Texas, this means that **when goods cannot make their trip in a fluid, efficient manner, Texas's economy is impacted**. The cost of doing business goes up, and there might be a negative impact on jobs.

Understanding freight fluidity—the performance of the trips that goods make—helps link transportation and everything a typical department of transportation, MPO, or local government transportation office might do with economic development. **Freight fluidity information puts transportation together with business to support economic sustainability and growth**. It helps you identify and reduce the bottlenecks so you can support the economy by making the most beneficial transportation improvements.

You may already be analyzing transportation performance and be aware of bottlenecks on the system, meaning points of major congestion, but **freight fluidity is about the trip**. The difference is thinking about the complete trip that goods make, what those routes are, and where the bottlenecks are occurring along the way—whether they are traffic problems on highways or delays at ports. **Freight fluidity is a way of thinking about freight transportation and seeing it through a different lens, the lens of the freight customer**. This may be the shipper monitoring freight from factory to store or the carrier concerned with efficient delivery. These are important customers of the transportation network.

A limitation of freight fluidity is that data for the entire trip goods make are not always available, and primarily only truck or highway data are easy to obtain. **The information in this guidebook helps to show how you can get useful information using highway analysis and how efforts are being made to make these multimodal connections.** This guidebook provides some ideas for multimodal analysis and ways to think about the relationship between performance and volume of trucks and multimodal connections like ships coming into port, as well as the impact of border crossings.

The guidebook is directly related to TxDOT's Freight Mobility Plan goals of:

- Economic Competitiveness—Improve the contribution of the Texas freight transportation system to enhance economic competitiveness, productivity, and development of the state.
- Mobility and Reliability—Reduce congestion and improve freight system efficiency and performance.
- Multimodal Connectivity—Provide transportation choices and improve system connectivity for all freight modes.
- Customer Service—Understand and incorporate citizen feedback in decision-making processes and be transparent in all TxDOT communications.

These are the primary goals from which freight fluidity stems, but freight fluidity also supports other goals and transportation functions you may have. These include safety, asset preservation and utilization, stewardship, and sustainable funding. **Freight fluidity creates an awareness of the types of goods movement or business supply chains that can assist in addressing these functions comprehensively. It can be integrated with safety, environment, and asset data to show freight bottlenecks along with these other categories for important freight trip corridors.** For example, you can layer freight fluidity mobility data with asset conditions, safety, and even environmental vulnerability along critical freight corridors to prioritize the types of improvements that will have the biggest benefit. Additionally, **freight fluidity information helps position TxDOT and regions for sustainable funding in that it provides highly defensible information to justify grant funding need in applications, especially federal opportunities, where addressing how both passenger and freight customer benefit, and sometimes freight-only customer benefit, is important**.

This guidebook is designed to make freight fluidity analysis as simple as possible. However, understanding freight flows can be a difficult task. There are so many goods moving by different modes to different businesses every day. There are supply chains for every product and supply chains for all a product's components. It is not simple to digest what is important to Texas and how to identify the transportation elements of these supply chains that TxDOT, MPOs, or local governments can influence and improve. Transportation agencies have a much easier time understanding how people move and how well transit works. When it comes to understanding freight movements, the freight flows are nebulous.

TxDOT, however, has invested in tackling the challenge of understanding how freight flows by focusing on freight fluidity analysis. In doing so, Texas is a national leader. Most states, MPOs, and local governments can only get a sense of truck volumes and maybe travel time performance using truck probe data. These data are travel time data derived from real trucks on the roadway and navigational devices like a global positioning system (GPS) or cell phone with mapping/GPS applications. Many states are assuming truck and passenger flows are similar and that they share bottlenecks, but Texas's work on identifying top bottlenecks shows that the freight experience is different from passenger traffic (Tembely & Schrank, 2020). **Adding capacity or changing operations to reduce bottlenecks based on passenger data may miss important opportunities to help a state or region's businesses with the significant freight bottlenecks they experience.**

It is important to identify the businesses or industries a transportation network supports and to know their travel time experience on Texas's transportation network, as well as how it differs from passenger traffic. Again, freight movers are important department of transportation customers. Practitioners and staff throughout agencies such as TxDOT need a sense of these customers and what parts of the transportation network need to be addressed to best help shippers and carriers sustain businesses and keep jobs.

Freight fluidity is an evolving concept, and as analytical and data capabilities grow, TxDOT and its partners plan to continue to build on the fluidity foundations that are reflected in this guidebook. TxDOT has a vision for freight fluidity going forward that can be further integrated into aspects of its operations. **The vision for freight fluidity in Texas is to provide freight fluidity measures on the multimodal freight network in Texas to inform freight investment and operational decisions that best benefit supply chains.** This vision means freight fluidity will offer complete and accurate visibility on how the Texas Multimodal Freight Network affects the transportation element of business operations and the economy in general. This vision for freight fluidity in Texas is expected to evolve, moving toward building out fluidity analysis across the Texas freight network and developing its multimodal capabilities. Ultimately, freight fluidity will be merged into statewide Traffic Operations Center or Freight Advanced Traveler Information System applications with near-time or real-time route performance and/or overall supply chain analysis.

For now, there are several ways that you can begin to apply freight fluidity analytics in your work, and this guidebook offers guidance you should consider. The goal is to guide you using resources that are currently at your fingertips and to provide simple steps that can be integrated into your current efforts so that freight is more strongly considered in planning, policy, project development, and operations.

1.3 How to Use This Guidebook

Table 1 is a matrix that you can use to determine which fluidity application would help you get the information you are seeking or be most relevant to you given your role. To use this information, follow the steps discussed below.

Step 1: Consider the questions you need to answer. Are you looking for information on what is moving or typical corridors or routes for freight movement? Are you interested in determining the economic opportunities that

How to Use this Guidebook

Step 1:
Consider the questions you need to answer.

Step 2:
Look at the resources in Table 1 based on your questions.

Step 3:
Or, identify your role first and then look at your primary or secondary uses and the types of resources and the questions they answer.

exist and considering how transportation can help grow economic development? Do you want to know what bottlenecks exist, especially along key corridors or freight routes?

If you are a planner, you might want to know all these things, and working through the steps to apply fluidity application in a variety of ways might give you the best methods to integrate fluidity into your work. If you are a key decision maker, you may be more interested in quick information about the types of goods moving, and, for example, you may want to check Texas' 100 Most Congested Road Sections to know what the top bottlenecks are for freight on Texas's system. This will give you bottleneck information quickly for your situational awareness (Tembely & Schrank, 2020).

Consider your needs and the questions you need to answer. Start with the yellow box. If you do not know the questions you want to answer, skip to Step 3.

Step 2: Look at the resources in Table 1 to see which ones are recommended to help you find the information on the questions you are seeking to answer. The page numbers are listed next to the resources.

Step 3: At the bottom of the matrix, there is information on users and primary and secondary uses of the resources. While there may be exceptions, this information is provided to help show at a glance which resources would be most relevant to the user by type. Thus, if you are unsure of the questions you are trying to answer, you may want to identify your role first and then look at your primary or secondary uses.

As Table 1 illustrates, this guidebook provides steps for the following types of analyses that support freight fluidity:

- What goods move in Texas?
- Where are the economic relationships and opportunities?
- How well does Texas's network perform? Where are the bottlenecks?
- What can be understood about multimodal impacts?
- Where can information be obtained quickly?

The following section provides guidance for these analyses and resources, and based on the questions you are looking to answer or the role you have, you can go to the most relevant pages for you.

Table 1. Matrix for Using the Freight Fluidity Guidebook—What Questions Are You Trying to Answer?

<table>
<tr><th colspan="2" rowspan="6">What Resources Are Available for Understanding Freight Fluidity?</th><th colspan="10">What Questions Are You Trying to Answer?</th></tr>
<tr><th>What Key Goods or Freight Move in Texas?</th><th>Page</th><th>Where are the Economic Relations and Opportunities?</th><th>Page</th><th>How Well Does Texas’s System Perform for Freight?</th><th>Page</th><th>What Can We Understand about Multimodal Connections and Impacts?</th><th>Page</th><th>Where Can I Get Information in a Hurry?</th><th>Page</th></tr>
<tr><td>Details on Freight Fluidity</td><td>7</td><td rowspan="4">Assessing Economic Conditions and Supply Chains</td><td rowspan="4">11</td><td>Framework Development</td><td>20</td><td>Port</td><td>27</td><td>Texas 100</td><td>32</td></tr>
<tr><td>Texas Freight Mobility Plan</td><td>9</td><td>Bottlenecks</td><td>31</td><td>Border</td><td>28</td><td>COMPAT/TCAT</td><td>33</td></tr>
<tr><td>Regional or Local Plans</td><td>10</td><td>Performance Measurement/ Visualization</td><td>20</td><td rowspan="2">Next Steps</td><td rowspan="2">34</td><td rowspan="2">FHWA Freight Mobility Trends</td><td rowspan="2">34</td></tr>
<tr><td>Freight Analysis Framework</td><td>10</td><td>Multimodal Trip Connections</td><td>25</td></tr>
<tr><th rowspan="4">Who Is the User?</th><th>Leadership/ Decision Maker</th><td colspan="2">Main User</td><td colspan="2">Main User</td><td colspan="2">Main User</td><td colspan="2">Secondary User</td><td colspan="2">Secondary User</td></tr>
<tr><th>Planner/ Policy Analyst</th><td colspan="2">Main User</td><td colspan="2">Main User</td><td colspan="2">Main User</td><td colspan="2">Main User</td><td colspan="2">Main User</td></tr>
<tr><th>Operator</th><td colspan="2">Secondary User</td><td colspan="2">Secondary User</td><td colspan="2">Main User</td><td colspan="2">Main User</td><td colspan="2">Main User</td></tr>
<tr><th>Industry Partners</th><td colspan="2">Main User</td><td colspan="2">Secondary User</td><td colspan="2">Main User</td><td colspan="2">Secondary User</td><td colspan="2">Secondary User</td></tr>
</table>

2. How to Use Freight Fluidity to Answer Key Questions: Applications for Freight Fluidity

This section provides guidance and steps that support overall freight fluidity analysis so that you can answer key questions, such as:

What moves in Texas and how?	What economic conditions exist and what are supply chain opportunities? What network should I look at to support freight flow?	How can I see bottlenecks or performance? How can I see multimodal connections and total trips goods make?

This section helps you walk through the types of activities necessary to conduct and make sense of fluidity analysis. Such activities include framing or framework development, measure identification, data, measurement methodologies, and results analysis (i.e., the "so what"). It also includes some additional details to clarify freight fluidity and how it is different from supply chain fluidity or overall supply chain performance, which you might hear about from industries. Further, this guidance is targeted to state, regional, and local agencies, describing applications for activities such as planning, economic development coordination, and traffic operations. It provides considerations for freight fluidity regarding international coordination and border crossing analytics, as well as multimodal applications such as connections to intermodal facilities and ship-to-truck analytics.

2.1 Details on Freight Fluidity

You may have heard about supply chains or supply chain fluidity. It is important to distinguish freight fluidity as a concept that is distinct, although related to, supply chain fluidity. When using products or commodities as units of observation, freight fluidity has been referred to as supply chain fluidity, claiming to measure performance of multimodal supply chains and associated freight networks. The performance of supply chains, in terms of fluidity, however, encompasses much more than transportation. It is more related to the concept of lead time, which includes not only the time it takes to transport goods to the end consumer but also the time it takes to complete all other processes that are involved in the order fulfillment activity. This may include everything from inventory management to order processing, production, picking, payments/collection, and even customer service. Only when comprising all these order fulfillment activities can the true end-to-end supply chain fluidity performance be assessed (Figure 1).

However, the work performed so far on freight fluidity for TxDOT and other public agencies has been **focused on the transportation activity only**, regardless of whether such activity is multimodal or not. For instance, the Federal Highway Administration (FHWA) is using freight fluidity to understand U.S. supply chains and explore data available and needed within the United States; the U.S. Army Corps of Engineers (USACE) is developing and implementing a freight fluidity management framework for U.S. maritime ports; and Transport Canada's success in building a freight fluidity program has been leveraged at different geographic levels and institutions to make decisions.

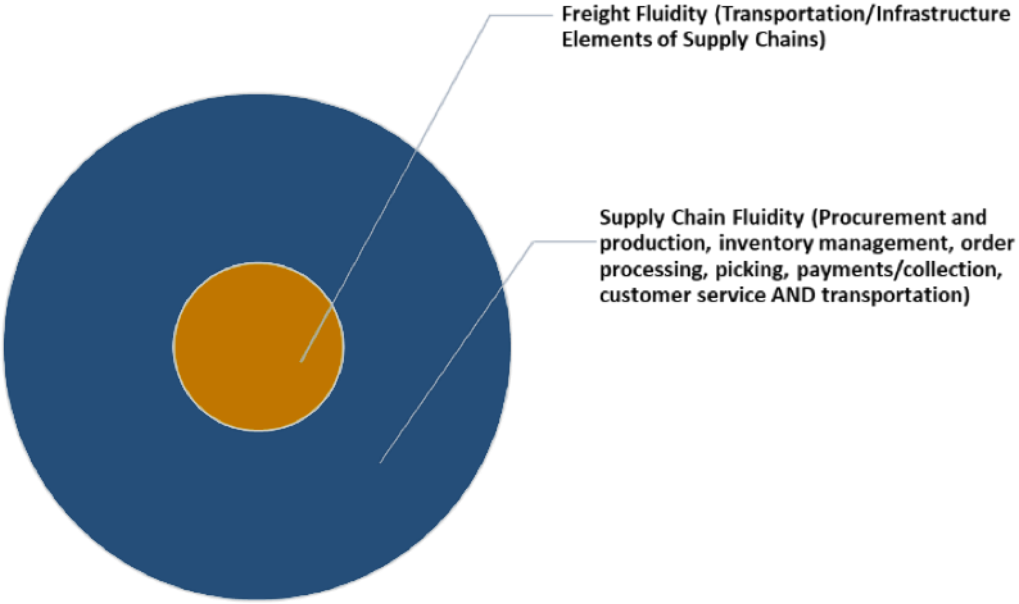


Figure 1. Freight Fluidity versus Supply Chain Fluidity

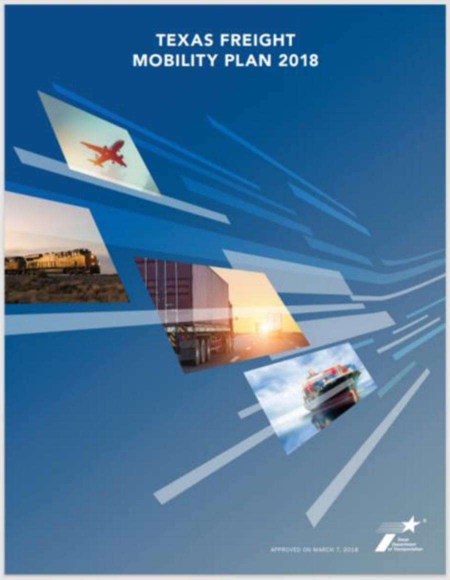
On the one hand, supply chain fluidity measures how fluid the entire set of supply chain activities, including transportation, is to deliver a product up to a certain endpoint (typically, the end consumer) from a given triggering event (typically, order placement). It is largely controlled by, and therefore more relevant to, the private sector, given the industry's need to increase service levels and asset utilization while lowering operating costs. Private-sector entities invest many resources in measuring supply chain fluidity and use a variety of technology options and data points to track goods through every echelon. You may have heard about Lean process improvement or other programs like Six Sigma that focus on manufacturing primarily but that have been applied to other parts of supply chain and even public-sector practices to identify waste in processes. They are two methods that the private sector uses when monitoring supply chain fluidity and looking for ways to reduce unnecessary steps or inefficient delays that add to the time and cost of doing business. **Transportation activity is one part of the overall supply chain measured** and bottlenecks and delays on the transportation network are a major cost to businesses that they seek to reduce.

On the other hand, freight fluidity measures how fluid the freight **transportation activity** is from a geographic origin to a specified destination and is largely influenced by the public sector for its importance in assessing how the current transportation infrastructure network is performing and where to allocate investments. The importance of this distinction lies in the relationship between the transportation infrastructure network (along with land use and other decisions in the public realm) and supply chain operations (i.e., private-industry decisions). Public-sector decisions regarding investment and management of the transportation network directly affect the private sector's supply chain operations.

Ways to Find What Freight Moves and How in Texas

There are several resources for getting information on what moves and how in Texas.

The best place to start is the Texas Freight Mobility Plan. It has information on types of goods, key industries, modes used (e.g., truck, rail), performance, and strategies.



Freight fluidity can be used by public decision makers at the senior leadership, planning, and operations levels for discussing freight movement on the transportation network and making investment and operational decisions, as well as for having discussions with key stakeholders and the public and being able to make transportation projects relevant to their economic concerns and awareness.

2.2 Analyzing Freight Movement in Texas: What Key Goods or Freight Move in Texas? How Are They Transported?

What is this analysis for?

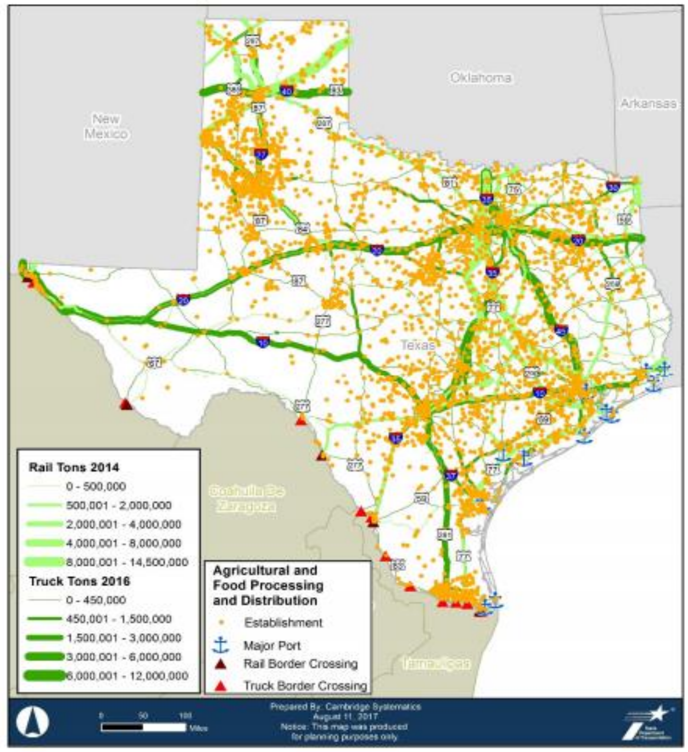
- Understanding what the top commodities are that rely on Texas's transportation network.
- Assessing the transportation network and the modes used to transport goods.
- Obtaining trends and forecasts in freight movement.
- Reviewing priorities and strategies for freight set by TxDOT and freight stakeholders.

At its simplest, a quest to understand freight fluidity should begin with a review of the ***Texas Freight Mobility Plan*** (TFMP). The TFMP is available from TxDOT online at https://ftp.txdot.gov/pub/txdot/move-texas-freight/studies/freight-mobility/2018/plan.pdf.

The TFMP provides the latest, most valuable information and details key statistics on the basic types of commodities and the transportation network used (TxDOT, 2018). It also provides details on strategies, policies, or programs in place, as well as the roles of TxDOT and partners in supporting freight movement. Figure 2 is an example of the type of information you can find in the TFMP, showing locations of major agricultural and food processing distribution establishments in relation to the Texas transportation network and the truck and rail tonnage moved.

Depending on the information you are seeking or the region you are either representing, planning, or operating, you may want to review regional plans. TxDOT has produced several regional plans, such as the Permian Basin Freight and Energy Sector Transportation Plan and the Rio Grande Valley Freight and Trade Transportation Plan. These types of resources provide more in-depth details on the goods moving in these regions, the related freight network, and any issues or challenges. This background is useful in simply understanding freight flows and bottlenecks that can be addressed through planning or operational projects. TxDOT provides its regional plans on the Freight Planning website at https://www.txdot.gov/government/partnerships/freight-planning.html.

In addition to the TxDOT-produced plans, you may want to see if your region has any plans produced by the MPOs or local governments, as well as other entities (e.g., universities). Many MPOs in Texas are advanced in freight planning and analytics and have produced numerous reports that can provide an understanding of goods or freight movement at different geographic levels. The North Central Texas Council of Governments (NCTCOG), for example, has a website devoted to freight around the Dallas/Fort Worth region that provides details on the Regional Freight Advisory Committee and its other plans and programs for freight movement (NCTCOG, 2021). The website is https://www.nctcog.org/trans/plan/freight.



Source: 2016 Truck Tonnage OD Data estimated based on TRANSEARCH 2010 base year data and Freight Analysis Framework version 4 (FAF4) Database FAF4 and assigned to the highway network using Texas Statewide Analysis Model version 3 (SAM-V3); 2014 Rail Tonnage OD Data estimated based on 2014 Carload Waybill Sample for Texas; 2014 Rail Tonnage OD Data assigned to the rail network using the Texas Statewide Analysis Model version 3 (SAM-V3); and 2013 establishment data from the Texas Workforce Commission.

Figure 2. Example of Texas Freight Mobility Plan Information for Agriculture and Food Processing (TxDOT, 2018).

Another resource for freight commodity and mode information is the federal Freight Analysis Framework (FAF) tool. This tool, provided by FHWA and the Bureau of Transportation Statistics (BTS), allows users to obtain state-level summary tables that provide statistics on tonnage and value by mode and commodity. There is also a web-based resource where users can select year, origin or destination, distance band, commodity, mode, and measure (tonnage, ton-mile, or values). Lists will generate depending on the information selected. For example, users can see the top state trading partners and the top commodities by tonnage and value. More sophisticated users may use the data in analyses with other data and illustrate the information through visualization software (FHWA/BTS, 2021).

It is important to note that the FAF provides estimates from many inputs. The tool is meant to provide a sense of the tonnage, value, commodities, etc., and the information is considered a sample to capture the freight data. Despite its limitations, the FAF is a free, easy resource available to help you understand what is moving, by what mode, and where. Other resources are available for this information, but they are costly. Generally, the more expensive data resources are used in plan development, such as for the TFMP. However, the FAF will provide some information that is useful in understanding freight fluidity at a minimum. Figure 3 shows an example of the FAF data tabulation.

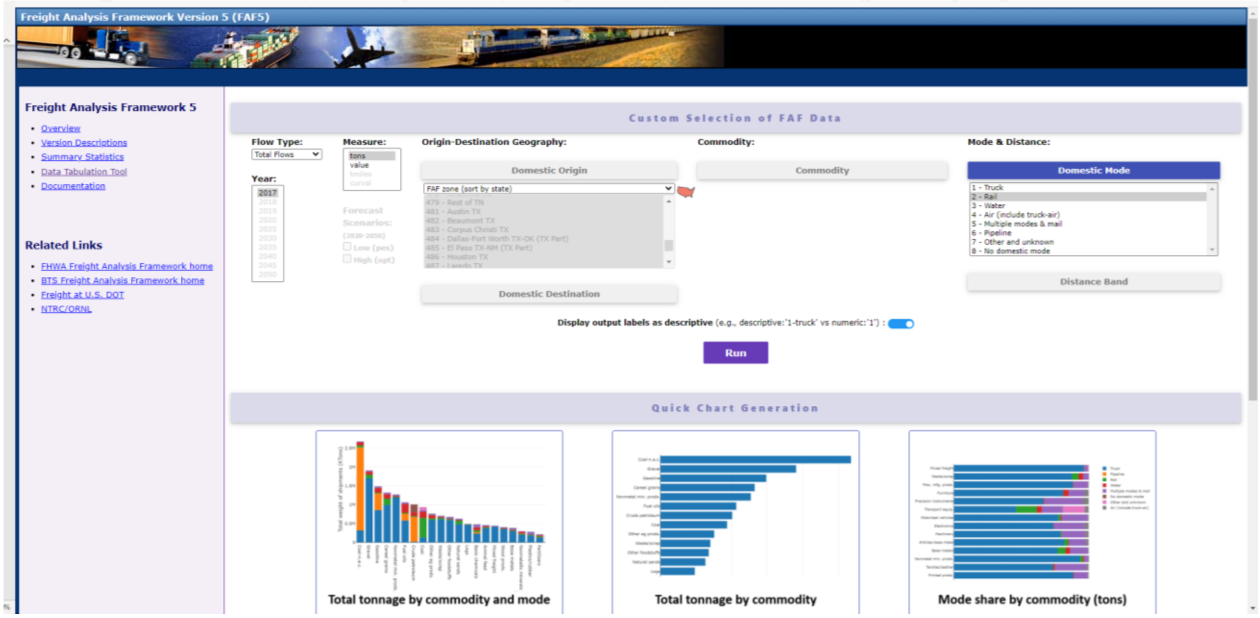


Figure 3. FAF Version 5 and the Choices Available to Get Information about Commodities, Modes, Value, and Tonnage (FHWA/BTS, 2021).

2.3 Assessing Economic Conditions and Supply Chains: Where is the Economic Opportunity? What Should I Know about Trade Partners or Where Opportunities Exist?

This section provides steps on using publicly available data to understand economics, trading partners, and potential economic development opportunities, which is useful in:

- Describing to leadership what commodities or businesses are critical in Texas and which states are critical trading partners.
- Understanding economic opportunity and where business growth could occur.
- Matching key trading partners and opportunities to the transportation network and defining which corridors are critical, especially for different types of goods.
- Partnering with economic development entities to talk about economic opportunities and what those trade routes look like.
- Helping system operators know what is likely moving on key corridors to create more awareness, especially if incidents or rerouting must occur.

Aside from consulting the resources available, such as the TFMP, one of the first and most critical steps in applying freight fluidity analysis for the state, MPOs, and local governments is to do an economic and supply chain opportunity analysis.

Why do this? This is the step that gives you some understanding of what is moving, who your trading partners are, and what kinds of commodities matter. This is the intel you need to connect the business and economic sector to the transportation network that matters to it. This information helps stakeholders talk about where freight is going or coming from and to think about the transportation network as the backbone, as well as how the network can support growth in economic sectors. It also helps show where there is opportunity or underutilized trade. For example, are there options to trade with states closer, or should you pursue growth in a different economic sector that is underserved?

You can do something similar and much less in depth by looking at plans such as the TFMP, Census, or economic development reports that have done some of this work for you by identifying top commodities or top industries. However, some of these resources become quickly dated, and you may wish to do something new. Doing the analysis described in this section is simple enough, despite sounding complex, and provides a wealth of information that sometimes does not get captured in plans. You can do this analysis with access to free, easy-to-navigate data, and it would take you only a few hours to put together. You do not need complex analytics or staff and consultant time.

2.3.1 Method

As mentioned above, the method prescribed in this section relies on publicly available data or economic information that can be assessed simply using basic tools such as Excel and/or Tableau. The data needed are from the Census Bureau and Bureau of Economic Analysis, and there are three key objectives for this methodology:

1. Identify products and markets Texas and its regions could incentivize, disincentivize, or shift in some way as part of a tactical supply chain plan. This objective determines the existing opportunities in terms of markets and products that Texas could acquire to establish new industries. It also provides the transportation and logistics services required for these new industries to thrive.
2. Understand the role of the statewide region in supply chains. The understanding of a region's supply chain role is the cornerstone to assess the adequate infrastructure and services the region needs to provide and develop. It also aids in identifying the capabilities Texas needs to develop to attract and establish the industries previously identified in #1 as opportunities.
3. Define Texas's current baseline economic activity in terms of the general economy, transportation, and supply chain activities. This baseline activity is the status in Texas based upon current services, activities, and economic levels. This status is the basis for a gap assessment between the current activities and the services and activities needed to grow and establish target industries in Texas.

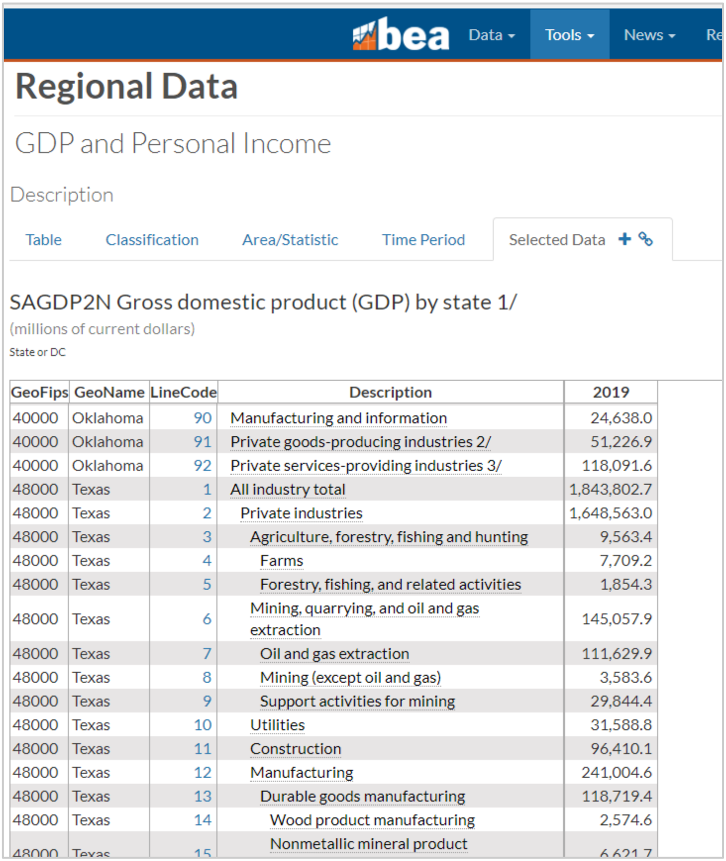
The following steps are best understood if you read them once and then try to follow along by going to the sites as they are listed. At first, it may seem complicated, but when you walk through the steps and websites, it will be easier to perform the analysis.

Step 1: To understand **top industries**, go to the Bureau of Economic Analysis (BEA) and download Regional Fact Sheet (BEARFACTS). BEARFACTS provides an initial overview of gross domestic product (GDP) conditions in Texas (or the region of interest). This information includes Texas's national ranking and top industry information. The link to BEARFACTS is https://apps.bea.gov/regional/bearfacts/.

Select "State" and then select Texas on the map. Next, select "State GDP." You will now see information on the top five state industries as a percent of total GDP for the latest available year. You can also get summary information about the change in GDP from the previous year.

Step 2: In this step, you will obtain **details on commodities and consumption**. You will need to do some data matching by downloading data for GDP **(goods production)** and personal consumption expenditures (PCE) **(consumption)** from the BEA data.

Sub-step 1: Use BEA interactive data to **assess commodity production and consumption**. Be sure to include Texas and surrounding states. Access the data at the following link: https://apps.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=1&isuri=1.



GeoFips	GeoName	LineCode	Description	2019
40000	Oklahoma	90	Manufacturing and information	24,638.0
40000	Oklahoma	91	Private goods-producing industries 2/	51,226.9
40000	Oklahoma	92	Private services-providing industries 3/	118,091.6
48000	Texas	1	All industry total	1,843,802.7
48000	Texas	2	Private industries	1,648,563.0
48000	Texas	3	Agriculture, forestry, fishing and hunting	9,563.4
48000	Texas	4	Farms	7,709.2
48000	Texas	5	Forestry, fishing, and related activities	1,854.3
48000	Texas	6	Mining, quarrying, and oil and gas extraction	145,057.9
48000	Texas	7	Oil and gas extraction	111,629.9
48000	Texas	8	Mining (except oil and gas)	3,583.6
48000	Texas	9	Support activities for mining	29,844.4
48000	Texas	10	Utilities	31,588.8
48000	Texas	11	Construction	96,410.1
48000	Texas	12	Manufacturing	241,004.6
48000	Texas	13	Durable goods manufacturing	118,719.4
48000	Texas	14	Wood product manufacturing	2,574.6
48000	Texas	15	Nonmetallic mineral product	6,621.7

Figure 4. Example of BEA GDP Table Output.

Select "Annual Gross Domestic Product (GDP) by State." Then select "GDP in current dollars (SAGDP2)." Next, select "NAICS (1997–forward)" followed by "Texas" and the neighboring states. Select every state that borders Texas, for example. Hold down the control button to make multiple selections of states. Then, in the "statistic" section, select "all statistics in table" and the unit of measure as "levels." Next, choose the year for analysis, being sure to consider which year has the most complete data. You can check this by selecting the most recent year and comparing it to a previous year to see if the fields are filled in or if there are missing sections. In general, it helps to go back a couple of years for the most complete data. This selection generates a table of GDP by the state and provides a line code and description of the industry area/commodity, as well as the total GDP in millions of current dollars for each line. An example of what you will see is in Figure 4.

Sub-step 2: Use the same process to access personal consumption expenditures. While GDP shows production or supply, PCE shows consumption or demand. The same link is used, but instead of selecting annual GDP, select "Personal Consumption Expenditures by State" followed by "Personal consumption expenditure (SAEXP1)." The same process as above is followed for selecting area, statistic, and year, but not NAICS, which is not offered. A table is provided showing line code, industry/commodity description, and total PCE in millions of current dollars.

Sub-step 3: To compare PCE and GDP, a crosswalk is necessary because the GDP industry lines do not match the PCE industry lines.

Table 2 provides the crosswalk needed to match PCE with GDP. They can then be compared for each state. Use the crosswalk to tally the PCE and GDP for the terms listed and develop a comparison sheet for each state.

Table 3 shows an example of how to line these up in Excel and compare the GDP number with the PCE number.

Table 2. PCE and GDP Crosswalk.

PCE Terms	GDP Terms
Durable goods	Durable goods manufacturing
Nondurable goods	Nondurable goods
Food and beverages purchased for off-premises consumption	Food and beverage and tobacco products manufacturing
Clothing and footwear	Apparel, leather, and allied product manufacturing
Gasoline and other energy goods	Petroleum and coal products manufacturing
Transportation services	Transportation and warehousing
Financial services and insurance	Finance, insurance, real estate, rental, and leasing
Housing and utilities	Real estate and rental and leasing
Health care	Health care and social assistance
Food services and accommodations	Accommodation and food services
Other services	Other services, except government

Table 3. Example of How to Compare PCE and GDP.

GeoNa	Description	PCE	GDP
Arizona	Durable goods	28076.6	22466.6
Arizona	Motor vehicles and parts	10513.2	(NA)
Arizona	Furnishings and durable household equipment	6313.7	(NA)
Arizona	Nondurable goods	53127.7	4915.5
Arizona	Food and beverages purchased for off-premises consumption	19567.5	(NA)
Arizona	Clothing and footwear	7446.1	(NA)
Arizona	Gasoline and other energy goods	6368.9	(NA)
Arizona	Housing and utilities	47972.4	50559.3
Arizona	Health care	39862.7	28106.4
Arizona	Transportation services	8516.5	10563
Arizona	Food services and accommodations	19612.5	12013.5
Arizona	Financial services and insurance	14377.3	73578.9
Arizona	Other services	17175.4	6563.2
Colorado	Durable goods	25175.2	14780.2
Colorado	Motor vehicles and parts	7722.9	(NA)
Colorado	Furnishings and durable household equipment	6576.3	(NA)

You can use these steps to generate numerous tables and graphs. You will be able to generate comparisons for each of the economic sectors, such as durable goods, nondurable goods, housing, health care, transportation services, food services, finance, and other. You can then compare the supply versus consumption of these sectors. Figure 5 displays an example comparison of PCE and GDP of transportation services by state. The figure shows that production of transportation services is higher than consumption in all states, which means the market is saturated for this sector.

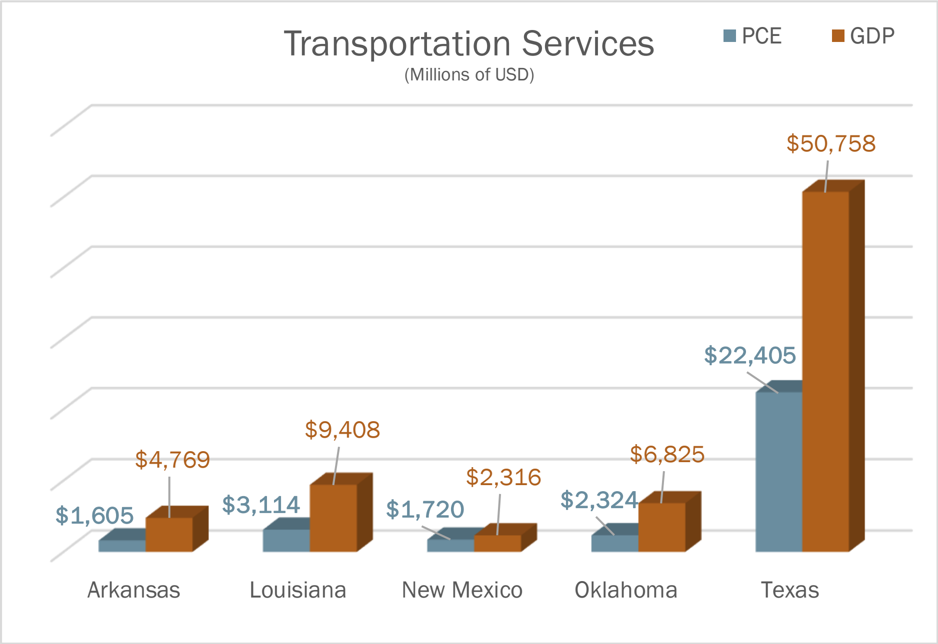


Figure 5. Example of Analysis of PCE and GDP for Transportation Services for Texas and Surrounding States.

Alternatively, when demand is higher than supply, economic sectors are undersupplied, which means there might be economic opportunity. You could look at ways to recruit these businesses, the likely transportation network these businesses might need, and then using the analysis of bottlenecks in the next section, you could identify what the mobility impediments are to supporting that type of economic development.

Similarly, you can look at the typical routes for the top industries in Texas and apply performance measures in the next section to evaluate these supply chain routes.

Step 3: To understand **freight flow information and supply chains or imports versus exports**, the Census Bureau Commodity Flow Survey (CFS) data can be used. The CFS provides data on business establishments for mining, manufacturing, wholesale trade, select retail and services, and their shipments originating from the business establishments and located in the 50 states and Washington, DC. Business establishments are asked to provide information for a sample of their individual outbound shipments for a one-week period, four times a year, and once in each quarter of the calendar year (United States Census Bureau, 2020).

The current data are factored for 2017. You can download the CFS public use micro-file at https://www.census.gov/data/datasets/2017/econ/cfs/historical-datasets.html.

Select either the SAS file or CSV file, based on your preference. Also, download the CFS Appendix A—Data Dictionary, which can help you understand the codes that are in the spreadsheet. You will need to use the Data Dictionary and filter for Texas using the FIPS code for Texas because the data set is large. You can then count by type of business establishment by industry class of shipper (NAICS) and mine the data for the following categories:

- Origin State (inbound shipments) (ORIG_STATE).
- Origin by Commodity (sort for origin [ORIG_STATE] and use SCTG for commodity, which is defined in the Data Dictionary, App A3).
- Origin by Mode (sort for origin and by mode, which is defined in the Data Dictionary, App A4).
- Destination (outbound shipments) (DEST_STATE).
- Destination by Commodity (sort for destination [DEST_STATE] and use SCTG commodity as defined in the Data Dictionary, App A3).
- Destination by Mode (sort for destination [DEST_STATE] and use mode as defined in the Data Dictionary, App A4).

For state-to-state flows and commodity flows, the data include both Great Circle distance estimates (SHPMT_DIST_GC) and route estimates (SHIPMT_DIST_ROUTED). The Great Circle estimate is the distance "as the crow flies" from location to location for shipments inbound and outbound. The route estimate distance is the estimate of the route of the freight flow from location to location. This information is helpful in that the greater the difference between the two, the less efficient the movement of goods. You can also determine origins and destinations by value (SHIPMT_VALUE) and weight (SHIPMT_WGHT).

One analytical feature you can add that you define yourself is desired distance. When creating charts depicting the Great Circle and route distances by origin, destination, and commodity, you can create an overlay to show desired distance. This is an arbitrary overlay meant to highlight what would be a desirable distance to and from your state for a good to travel. You might choose 800 or 1,000 miles, for example. You should generally use a desired distance of around 800 miles or below for the most important traded commodities. You may wish to adjust this distance depending on the market. However, despite being arbitrary, the application of this overlay is meant to highlight commodities and state trading partners nearer or farther from Texas to illuminate the role distance plays and if there are opportunities to target economic development activities to shorten supply chains.

As an example, this type of analysis was done for TxDOT in 2017 (Monsreal, 2017). Figure 6 shows that retail trade in Texas has a much lower level of sales than wholesale trade, and the difference between manufacturing and wholesale value is more than 200 percent the value of manufacturing sales. Since the two have different levels, this could indicate that Texas's wholesale trade may be serving inbound and outbound shipment companies and is regionally significant since it may be serving other states. This helps see Texas' position the trade of goods.

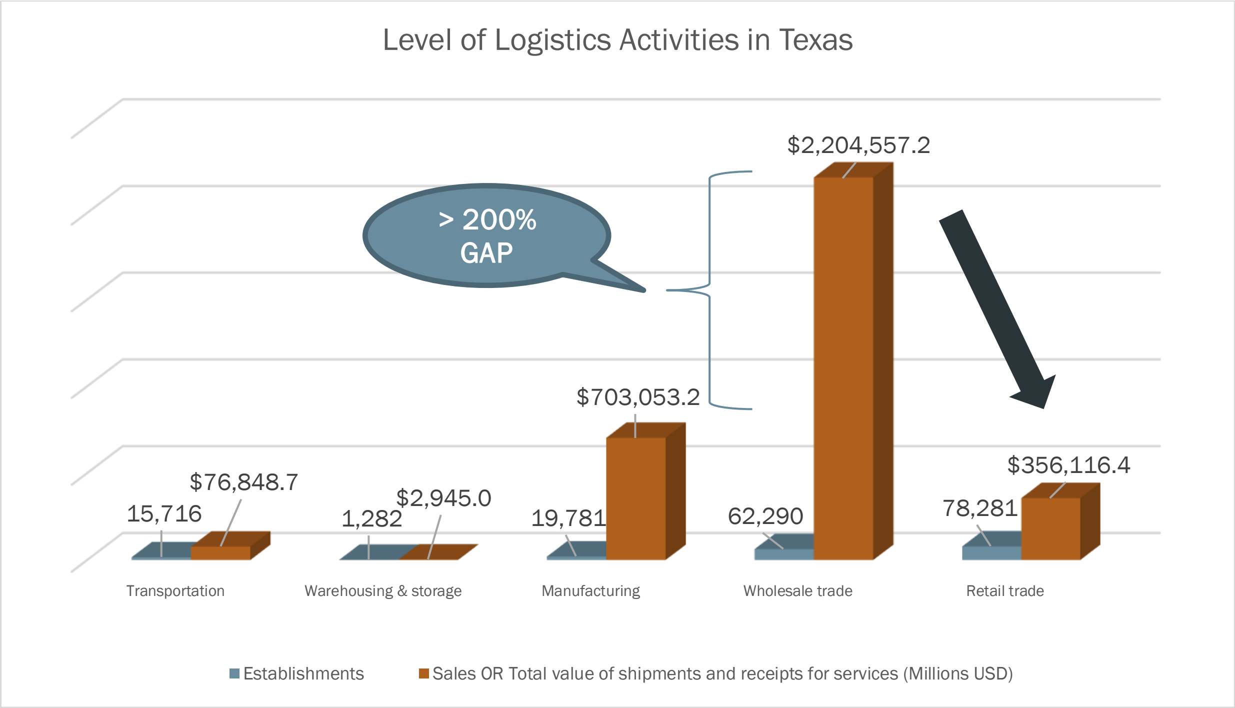


Figure 6. Example of Commodity Flow Survey Data Graph for Establishments versus Sales.

Another example is in understanding Great Circle and route distances of primary inbound shipments by origin. In Figure 7, the shaded area represents the distribution of desired distances, in other words, how far Texas would want to be trading. For assessing how supplier states fall within this desired distribution, the X axis of Figure 7 keeps Texas's supplier states sorted from the most (Texas) to the least (Arizona) important in terms of

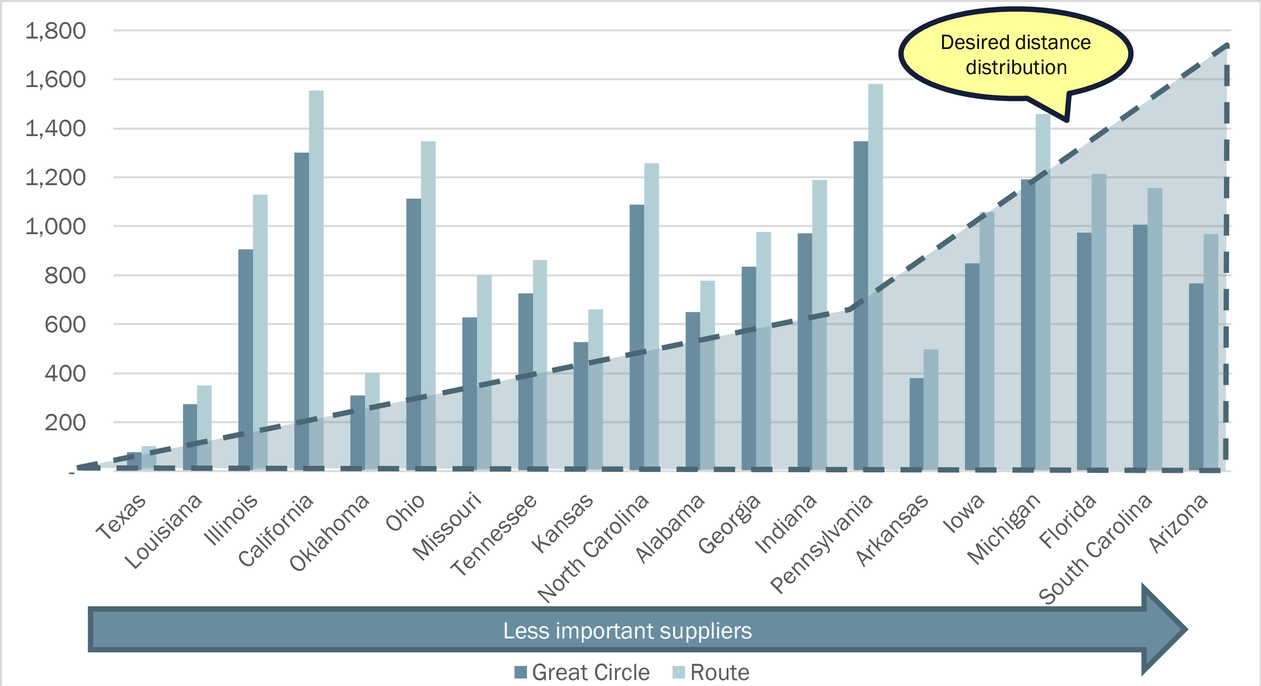


Figure 7. Example of Inbound or Supplier Analysis with Great Circle, Route, and Desired Distance Distribution.

value. Notice that Louisiana, Illinois, and California distances (Great Circle and route) fall outside the shaded area (although Louisiana is a neighboring state). This means that Texas could attempt shifting the supply importance of these states down the supplier's rank by substituting their products with domestic or neighboring (i.e., closer suppliers) products. Texas can identify the goods coming from these places and understand ways to recruit these industries to support inbound supply to Texas in-state or closer, which may reduce cost of product supply chains that ultimately impact the cost of goods and doing business for Texas.

These are just two examples of the types of information this analysis can provide to illuminate economic relationships and opportunities. However, if you follow this process, you can generate numerous graphs and charts and look at the data in a variety of ways for the regions or corridors of interest to you. This will help develop robust details on the types of economics and supply chains at play and where there are options to attempt to shift suppliers or customers of Texas.

When considering this information, you can use the maps and elements in the TFMP or other regional and MPO plans to look at which routes would best support the suppliers or customers most critical for Texas or most important to grow relationships. For example, if you identify a supply chain route from Texas to Florida as a critical export, you will want to look at the typical routes freight might take between the two states. You can then use the steps in the next section to identify bottlenecks and ways to make these routes most efficient, which can help with the goals you may identify in this analysis for economic sustainability and opportunities.

2.4 Assessing Freight Mobility and Bottlenecks: How Well Are Freight Corridors Moving Freight?

This section provides an overview of steps to follow and available resources for understanding how well freight moves on the Texas network. Use this section to understand:

- Where key bottlenecks are occurring.
- Where congestion is reliable (routinely congested) or unreliable.
- What the relationship is between highway and port and border crossing activity.

Depending on your role in transportation, you may already be used to looking at performance, especially mobility. You may already have a program in place to look at congestion and bottlenecks. This is certainly true if you work for TxDOT and are familiar with the Texas' Most Congested Roadways project that ranks bottlenecks throughout the state for all vehicles and trucks. You may be getting phone calls or e-mails about congestion in your region and have had many discussions about known bottlenecks.

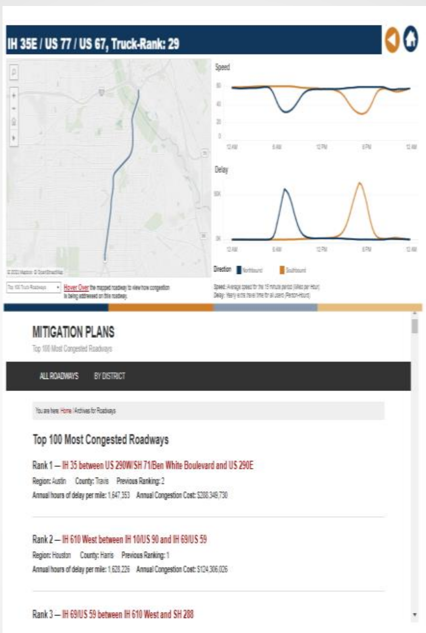
Analyzing freight mobility performance for fluidity is not a stretch from what you are used to, but it instead involves **considering the trip**. So, instead of looking at a segment or ranking by segments and looking at all traffic, the focus here is on considering the point A to point B corridor or supply chain route for goods into, out of, and within Texas. The process involves reorienting understanding travel times, speeds, and areas of significant congestion by thinking about the trips. Considering mobility along the trips that goods make helps propel traditional freight transportation performance analysis of congestion and reliability by adding an economic relationship through the supply chain perspective, especially when coupled with economic/supply chain awareness or the analysis from Section 2.2.

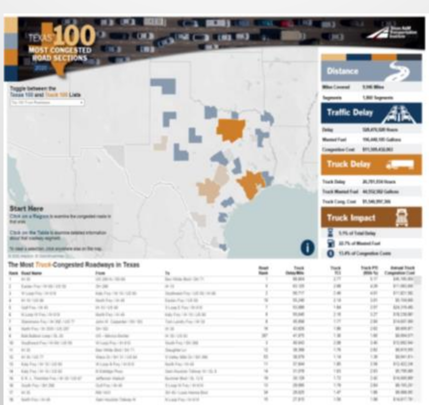
You may be wondering this: If freight travels by multiple modes, don't I need data for all modes used during a trip? The freight could come into the port, transfer to train, and then be put on a truck. If I am considering the full trip, won't I need travel time information for each of those trip legs? In a perfect world, yes. The only way you can truly see the freight experience is by having multimodal data for all the legs of a trip. This has been a challenge for freight analytics in general in that for the most part, only truck data for travel times or mobility are available. The data mostly come from GPS devices in vehicles or from cell phones used by drivers in cars and

Where Are the Bottlenecks?

TxDOT has several important resources you can access to see bottlenecks.

Texas' 100 Most Congested Road Sections is a great place to start in looking to see where bottlenecks are on key freight routes of interest.





trucks using navigational applications. The data may also come from Bluetooth or other data capture devices, but truck travel time data (or truck probe data) are ubiquitous through several providers. FHWA provides the data for free to states and MPOs as part of the National Performance Management Research Data Set (NPMRDS). There are also some data sources for vessel movement and aircraft delay, and railroads have occasionally offered some mobility data.

Despite not having multimodal data, the highway component of freight trips is valuable. Having this information has helped transportation agencies understand freight so well that even without multimodal links, thinking about the highways as part of trips or supply chain routes is important. Later in this section, there are some recommendations for multimodal links, reflecting the strides that TxDOT has made to connect trip legs.

2.4.1 Method

The methodology for this analysis involves three key elements.

- **Framework:** The first element is to develop a framework for fluidity analysis relevant to what you want to know. What questions are you trying to answer? Are you concerned with where freight is stuck in bottlenecks? Are you interested in how well freight moves on one corridor or another or the trips for a particular commodity of interest? This information involves stakeholder discussions on what matters, what measures are important, and what goals and objectives you want to analyze. In other words, here is where you get to determine what is important to you—to Texas or to your region. What do your stakeholders value? You can prioritize that information in this type of analysis.
- **Economic Opportunities and Routes That Support Freight Flow:** The second element is to combine the framework with assessments of economic conditions in Texas or the region (as described in the previous section) and focus on strengths and opportunities and awareness or context for the fluidity analysis. What trading partners are critical to maintain, and what are the likely routes used? What trading routes appear opportunistic that you want to assess or monitor? Here is where you can identify the important trips that should be measured.

- **Performance Measurement:** The third element is the application of fluidity analysis and the assessment of freight flows and bottlenecks along trip routes identified to answer the questions that you have framed. There are two important considerations when performing this step. First, fluidity is useful in understanding freight bottlenecks and providing information that decision makers can use to make transportation investments and policies that best support and grow the economy. Second, fluidity, though useful, must be used as a resource and in conjunction with other information or contexts.

The framework and performance measurement elements of this analysis are described below.

(i) Framework Development

The first part of applying fluidity analysis to understand mobility and bottlenecks is to develop a freight fluidity framework. This framework will provide a foundation and roadmap to help you think through the questions you want to answer.

First, it is important to think about the following questions:

- What is freight fluidity and what does it mean to me (for Texas, for my region, etc.)?
- What are specific freight fluidity performance measures? What kinds of performance do I want to measure (mobility, reliability, costs)?
- What data are available to support the measures (truck probe data, truck volumes, tonnage, and value)?
- What are possible calculation procedures for the measures (which metrics will I use)?

The answers to these questions can help frame this analysis and organize what you are looking to answer. Table 4 shows the components you will want to frame in answering these questions in detail. Table 4 also presents the idea of organizing this analysis by performance and quantity questions and measures with analysis on the where and how well freight is moving, categorized as performance, or “P’s,” and on how much freight moves as quantity, or “Q’s” (Eisele & Villa, 2015). You will need to consider the geographic area of interest to you, which might be a specific route, supply chain, or urban/local, state, region, or global area (Eisele W. , 2017). The analysis presented in the previous section can help illuminate the likely routes of trips to measure.

Table 4. Framework Development for Fluidity Analysis.

Components	Description	Selected Suggested Measures/Considerations[1]
Performance (P's)	How well are the links/nodes and network operating? Where are there bottlenecks in the system?	• Mobility (e.g., travel time, total delay, delay per mile, travel time index) • Reliability (e.g., planning time index) • Costs[2] (associated with delay, unreliability, wasted fuel)
	How well does the system (infrastructure, users, agencies) react to disruptions (i.e., how resilient is the system)?	Resiliency[3] has four aspects: • Robustness (ability to withstand disruption, measured in time) • Rapidity (time to respond and recover) • Redundancy (alternate route [capacity] availability/access within a certain travel time) • Resourcefulness (ability and time to mobilize needed resources)
Quantity (Q's)	How much freight is moved (and where)?	• Volume (e.g., number of trucks, railcars, twenty-foot equivalent units [TEUs]) • Weight (e.g., pounds, tonnage) • Commodity value[2]

[1] These selected measures and considerations are ideally obtained by mode and by commodity for complete freight network evaluation.
[2] Costs in the performance component and value in the quantity component capture the economic impact of freight fluidity.
[3] Resiliency is an element of the performance component because current system resiliency is captured in measures of mobility, reliability, and associated costs. Note that the 4 R's (robustness, rapidity, redundancy, resourcefulness) of resiliency can typically be expressed in time, and hence, delay and associated cost measures. Resiliency is included in the freight fluidity framework here because it is critical for efficient goods movement during system disruptions. Evaluating and improving transportation system resiliency during disruptions serves to promote understanding and improve performance during challenging times of goods movement.

Using the idea of P's and Q's, the fluidity approach can be scaled to different geographies of trips by tailoring the questions and measures for the region of interest. If you can collect multimodal data (more detail on that later on), you can apply the questions and measures to those data and expand your analysis.

Once you have the analysis framed and your trips identified, you can apply the measures identified as described below.

(ii) Freight Fluidity Mobility and Bottleneck Analysis

There are several processes you can follow to answer the questions framed through the measures identified. Depending on how detailed you want to get, the processes range from simply consulting available performance information to running travel time traces or advanced analytics. These processes include:

- Urban Area Mobility Information: This process allows you to understand performance of the urban region for your route or freight corridor of interest.
- Freight Corridor Mobility Information: This process can provide detailed bottleneck location information and performance statistics for specific routes.
- In-Depth, Location-Specific Information: This process includes applying travel time analytics resources and methods to understand performance more specifically for the route of interest.

Process 1, Urban Area Mobility Information: There are several resources available for understanding performance of important routes for freight trips. One of the first to consult should be the *Urban Mobility Report* (UMR). While the UMR does not provide specific route information, it can show trends of congestion in the urban area of the route or corridor of interest, and this information can help you get a sense of congestion. The UMR provides rankings of where locations throughout the United States stand in terms of congestion nationally. The UMR offers congestion data for commuters and freight in 471 urban areas across the United States (Lomax, Schrank, & Eisele, 2019).

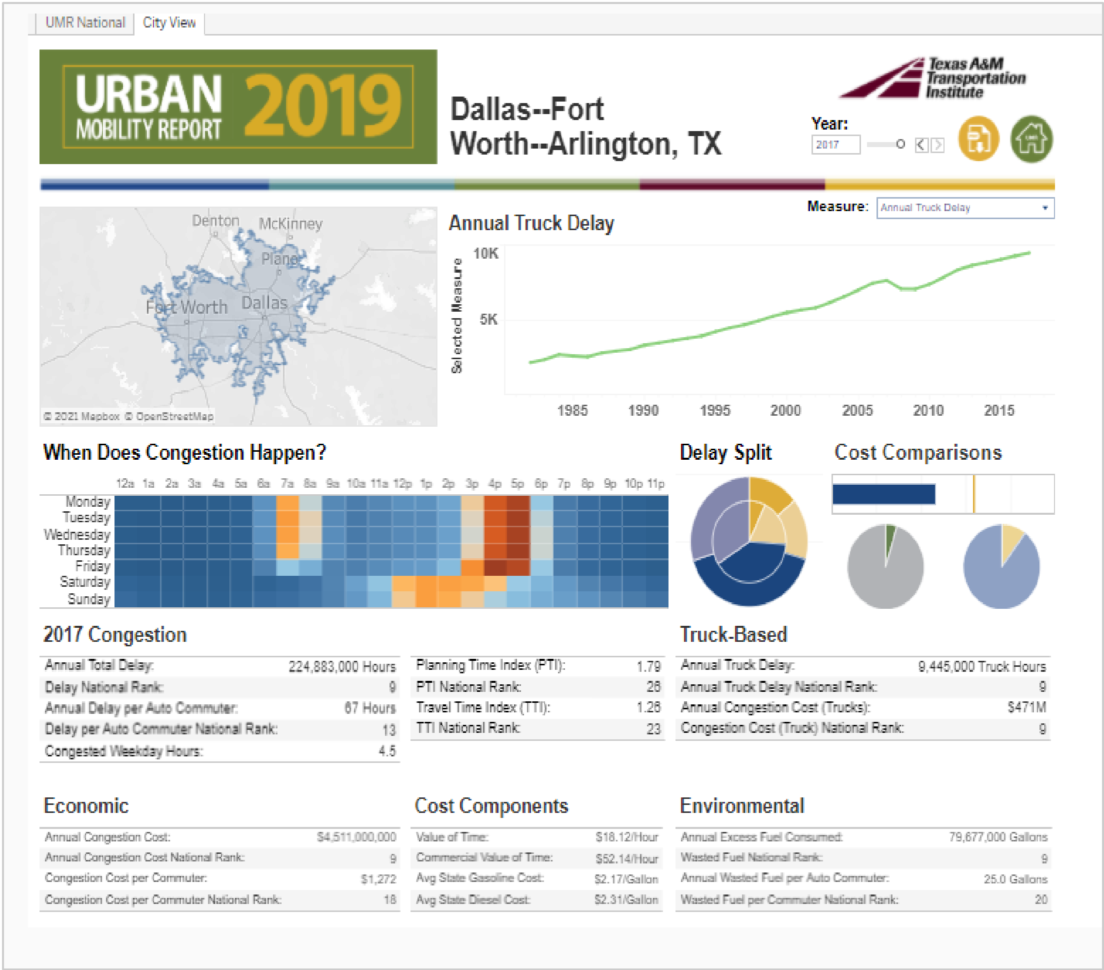


Figure 8. Urban Mobility Report Output for Dallas/Fort Worth/Arlington.

Consulting this resource can provide measure results for geographic areas in Texas with significant freight activity. For example, you can obtain mobility and reliability measures, congestion cost, national rankings, and environmental measures. Figure 8 shows an example of what the UMR can provide.

Process 2, Freight Corridor Mobility Information: Another important resource in understanding fluidity is the [Texas' 100 Most Congested Road Sections] (Texas 100), which provides rankings of the most congested roadways from commuter and freight perspectives. A statewide ranking is available for truck delay per mile, truck planning time index, and annual truck congestion costs for segments throughout Texas. You can identify if the highway component of the trip or region of interest has bottlenecks, the ranking among others in the state, and the severity along with congestion costs (Tembely & Schrank, 2020). This information can go a long way in illuminating the highway portion of freight trips, and it helps when comparing multiple trip corridors. This information is also a way to see the bottlenecks. Though TxDOT is only legislatively mandated to list the top 100, the Texas 100 resource looks at approximately 1,800 segments across the state. It is likely that the road you are looking for will be covered and you can see what bottlenecks exist.

Process 3, In-Depth, Location-Specific Information: For more in-depth analytics, you can use a truck probe data source, such as the NPMRDS, as well as truck volumes and FAF tonnage and value data available from FHWA to perform travel time traces along trips and visuals, such as contour maps and heat maps, of any of the performance measures. Tools like Excel or Tableau will help you perform these types of analytics, although travel time traces may require advance data processing. The travel time traces are a way to look at how long it takes for trucks to make a trip from one point to another (origin to destination) by time of day. According to Eisele (2017), "Travel-time traces show the average travel time and the 95th percentile travel time for a length of roadway beginning at various times of day. The 95th percentile time reflects the variability in the travel times through the corridor due to construction, crashes or other incidents." You can work with the truck probe data and organize it based on a particular route to calculate the delay and travel times by time of day for the entire route. Again, this may require more advanced analytics and access to data such as the INRIX Trips origin-destination waypoint data. However, simply looking at the travel times in the NPMRDS, for example, by time of day and then using graphing options in SAS, Excel, Tableau, or ArcGIS can help produce effective illustrations of how routes are performing.

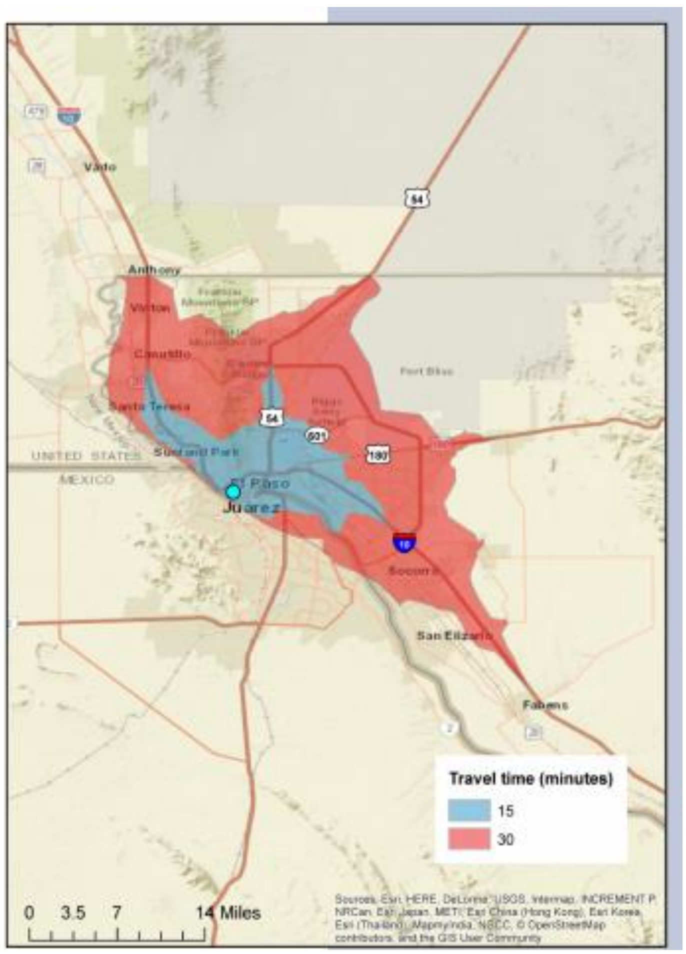
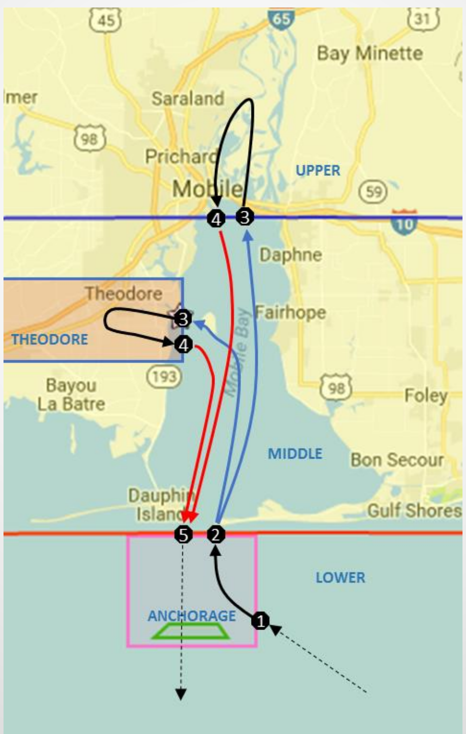


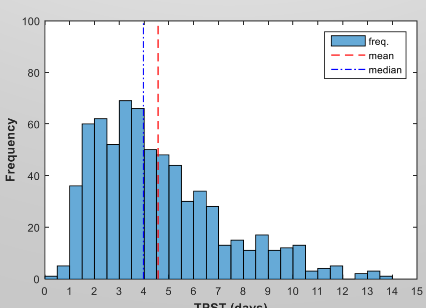
Figure 9. Example of Contour Analysis as Part of a Fluidity Analysis for El Paso Trip Routes.

Contour maps show regional travel times for a selected time of the day to or from a freight generator, such as an airport or port. The most congested corridors have a shorter distance from the generator to the contour. Heat maps use GPS data to show vehicle paths (trips) crossing a selected segment during a certain time period, revealing problematic areas and providing a greater understanding of freight traffic flows (Katsikides, Eisele, Schrank, Mays,

USACE Freight Fluidity Management Framework for U.S. Ports

A USACE study looked at vessel travel time in the River Harbor for the Port of Mobile in Alabama and found that the mean travel time for ships was 4.5 days but could be as high as 14 days.





Source: Kruse and Eisele (2017).

& Wells, 2018). Figure 9 is an example of a contour map analysis for trips in El Paso showing travel times.

2.4.2 What Do We Know about Multimodal Connections?

As mentioned above, until now, most of the advancements in freight fluidity have focused on truck movements on the highways, but freight trips are not just limited to the highway components. The limitation is due to data availability for other freight modes. Truck data are ubiquitous, while multimodal data, such as ship, air, and rail data, are much more difficult to obtain. However, there is advancement, especially with ship data, to connect these legs of freight trips.

To truly understand the behaviors and life cycles of freight movement, you must consider its multimodal relations. Considering other modes of freight movement is more challenging because the data are not readily available to transportation planners, and the modes are not as prevalent in planning and investment discussions.

Recent projects in Texas, in Maryland, and by the United States Army Corps of Engineers (USACE) have been able to make multimodal connections. These connections have involved using the following types of data:

- USACE Automated Information System data on vessel movements in channels (Kruse & Eisele, 2017).
- Lloyd's Register data for vessel activity.
- Census and local awareness of commodity data.
- Gathered data from terminal operations and port company performance reports.
- Private, purchased terminal capacity data.

With this information, connections and relationships between vessel, terminal activity, and truck performance have been pieced together for a picture of multimodal trips. Demonstrating this relationship has helped to advance the justification for multimodal data and to illustrate to the freight community how important it is for the public-sector agencies to have the ability to understand the full trips.

For example, the Maryland Department of Transportation and USACE studied dwell time at terminal areas and matched it to key freight fluidity routes of interest (Figure 10) (Eisele, Kang, & Monsreal, 2019). TxDOT has identified truck volume impacts related to ships coming in and out of its ports. This work has helped understand how truck volumes are impacted when different types of ships come in and out of the port area (Eisele & Monsreal, 2018).

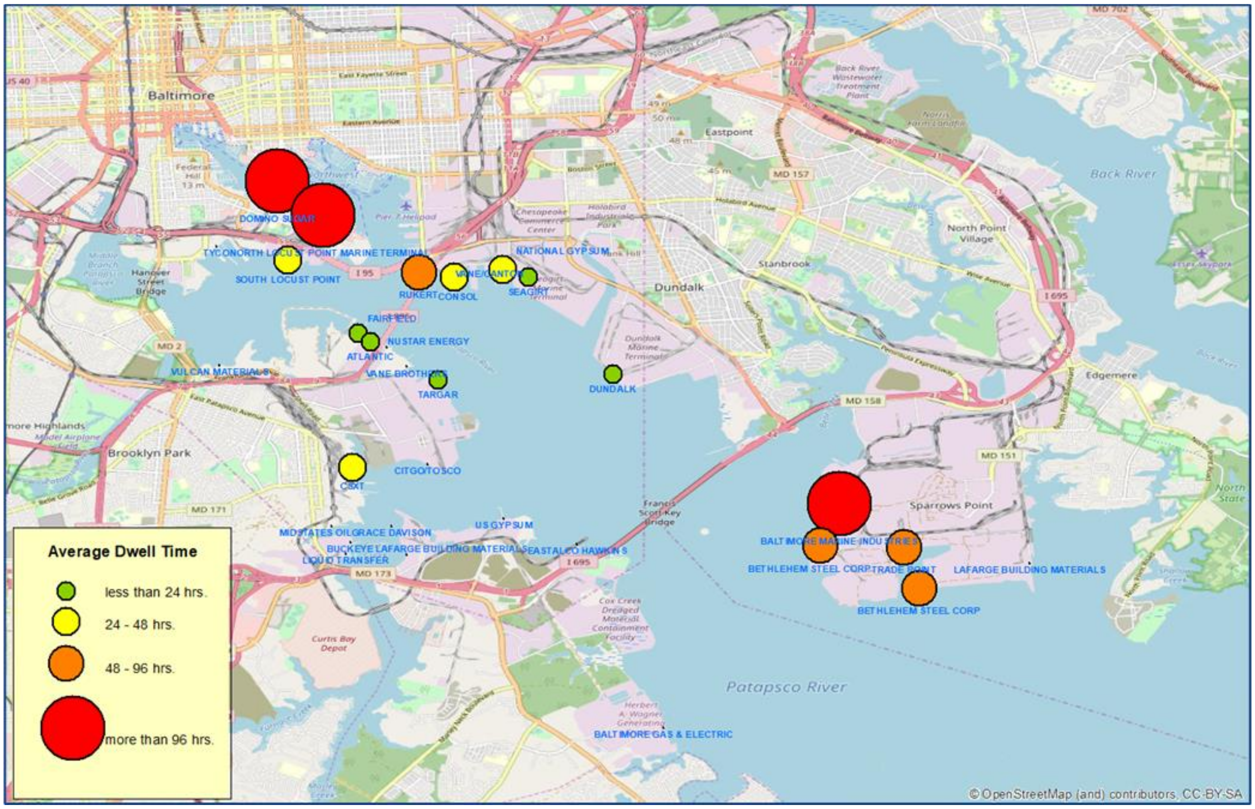


Figure 10. Port of Baltimore Dwell Time Analysis (Eisele et al., 2019).

At this point, the multimodal methods are not advanced enough to fully fold them into the mobility analytics described in the section above. However, you can apply the same measures and processes for travel times/performance visualization if you are able to obtain multimodal data.

Another option is to look at truck volumes and what happens to them when activity occurs at ports, airports, or intermodal facilities. Truck volumes are available from TxDOT's Statewide Traffic Analysis and Reporting System at https://www.txdot.gov/inside-txdot/division/transportation-planning/stars.html. For example, when a big ship comes into the port, look at what happened to truck volumes at different time periods prior to its arrival, on the date of arrival, and then at different intervals after it leaves. This information will, at the very least, give you a sense of magnitude or impact on the highway leg of the trip freight makes into and out of the port.

In a recent analysis of the Port of Brownsville for TxDOT, truck volumes were assessed to show impact in relation to port activities (Eisele & Monsreal, 2018). The truck volume on the highway network in a port community is not stagnant, nor is it entirely influenced by the port activities. Like any city, many activities contribute to freight volumes, but a port has an out-sized influence on the network. Vessels coming into the port may begin to influence roadway volumes as early as three weeks before the vessel's arrival as freight, containers, and other supplies are staged at the port. Likewise, the vessel may impact roadway volumes several weeks after it has docked (Eisele & Monsreal, 2018). Figure 11 shows an example of the baseline truck volumes and the increase relative to the vessel's arrival.

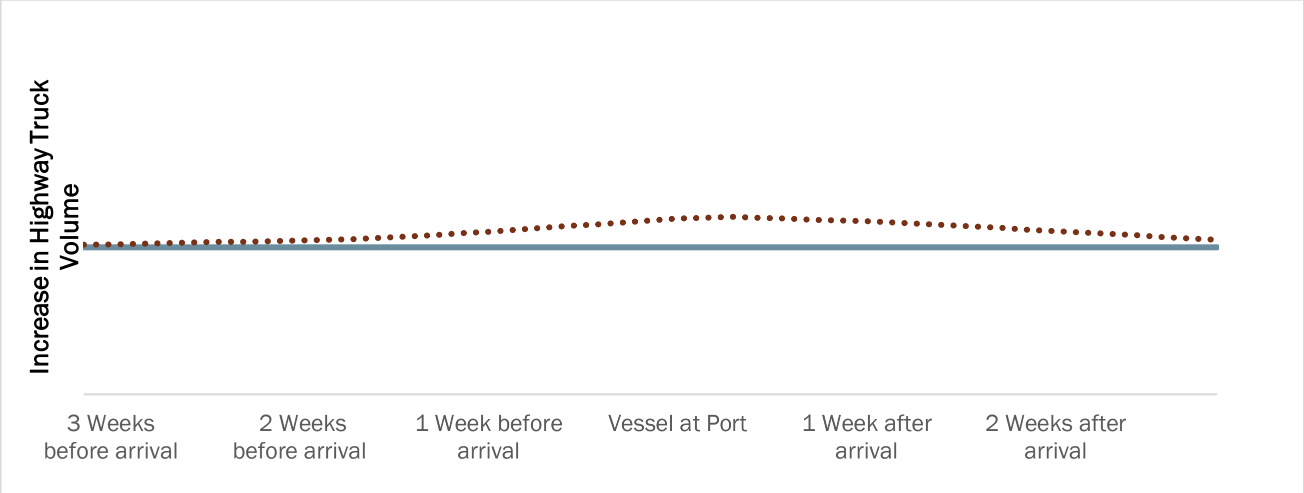


Figure 11. Illustrative Change in Truck Volumes Relative to Vessel Docking.

Planners can use the calculator in Appendix B that is derived from the Port of Brownsville data set to see how trucks are impacted over time in relation to ship calls. While this is a specific example, the takeaway is the level of magnitude of impact on truck volumes and the fact that there is a relationship.

As these multimodal methodologies mature, and as you obtain access to data and analytics in the future to show the multimodal leg of freight trips, you can begin to incorporate this process into your thinking by having an awareness that there is a relationship, and a simple way to see it is to monitor volumes.

2.4.3 Border to Highway Fluidity

For Texas and many border regions, the border crossings are a critical part of the freight trip that you will want to analyze. There are data on border wait times, but challenges exist in understanding travel times across the border with the truck probe data that are available. You can, however, obtain some information from truck probe data sets and awareness of wait time that you can piece together with travel time analytics from Section 2.3 for a view of border-related trips.

TxDOT has made advancements in border fluidity analysis, and work continues to help match border crossing elements with overall freight fluidity analysis because border crossings are a critical link in Texas and national freight flows. The border crossing process is complicated, with multiple stakeholders. For example, while some freight crosses the border by truck or rail on its original vessel, often there is drayage across the border, which is an added step in the process.

Using the Border Crossing Information System, border crossing time has been found to be unreliable, meaning that there is a high variability of travel times. Figure 12 shows crossing time and reliability for the Zaragoza-Ysleta International Bridge in El Paso over a period of days, and the crossing time varied significantly.

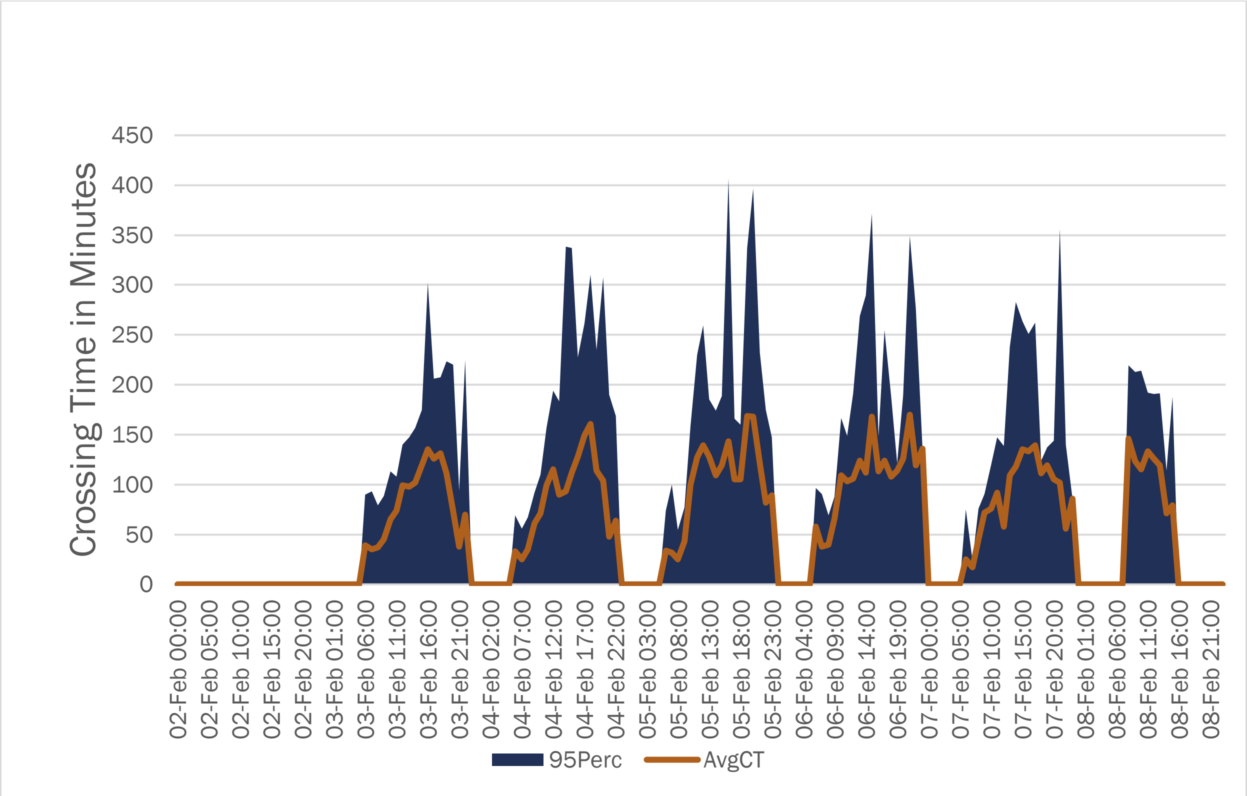


Figure 12. Crossing Time and Crossing Time Reliability Measures at the Zaragoza-Ysleta International Bridge, El Paso.

This type of information coupled with highway fluidity measures can help show the trip that cross-border goods make. If you are interested in a cross-border commodity or freight corridors, you can obtain the travel time at the border and match it to the types of analytics from Section 2.3.

2.4.4 Estimating Cross Border Fluidity

TxDOT has developed a Cross Border Fluidity Estimation tool in Excel that is based on a set of data sources and helps a user estimate cross border fluidity. It provides information for seven border crossings by travel time, sample sizes/counts, and speeds. This information is presented as estimates by time of day and day of the week. The purpose of this is to function as planning-level estimates to inform stakeholders of the end-to-end mobility statistics along the entire border. When developing this program, several major datasets were merged. These data are from HERE and the Border Crossing Information System (BCIS), and they provide information for over 7 million trips. These data were transformed into estimates so that users of the tool could have a reliable estimate of crossing activity for the different stages of the crossing process.

The information in the tool includes:

- Travel Time Estimates
- Sample Size/Counts of Trips
- Speed

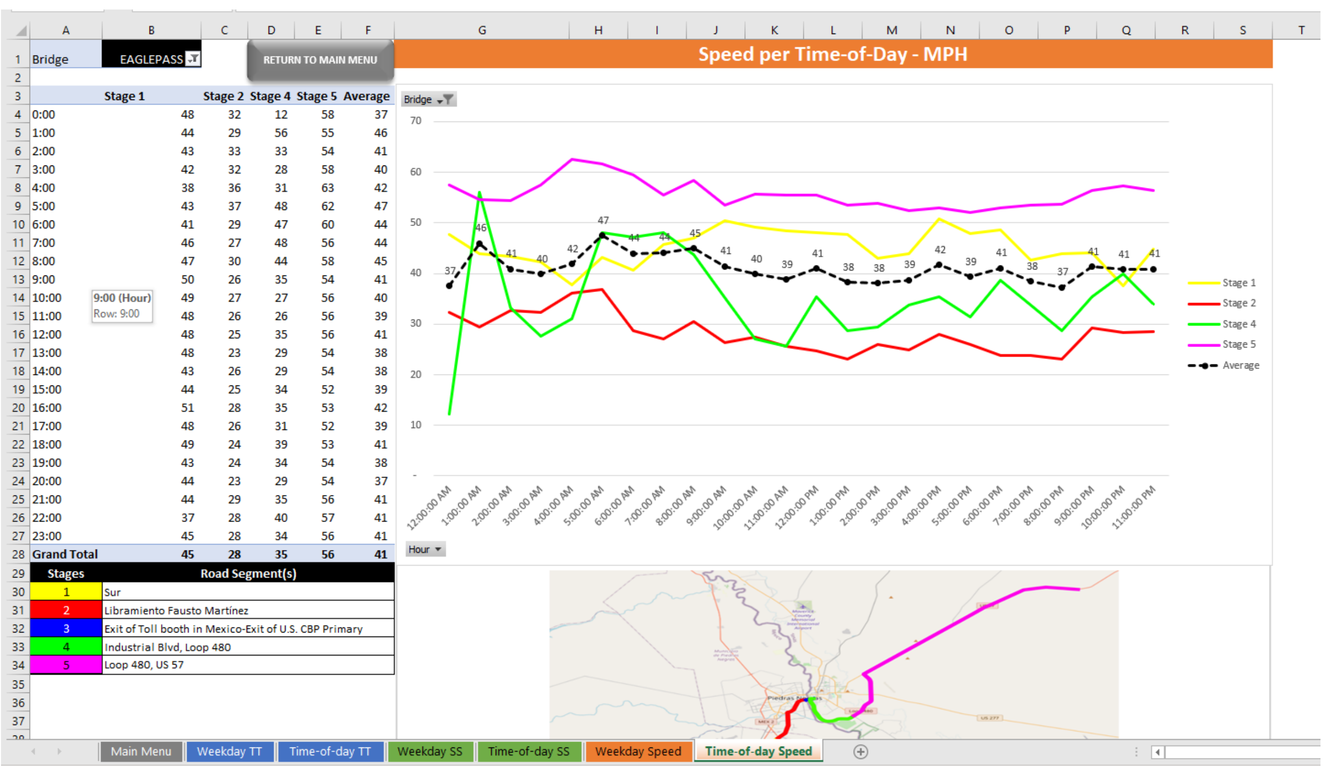
There are seven border crossings covered in the tool:

1. Veteran's Memorial Bridge, Brownsville,
2. Pharr-Reynosa International Bridge, Pharr,
3. World Trade Bridge (WTB), Laredo,
4. Colombia Bridge, Laredo,
5. Ysleta Zaragoza Bridge, El Paso,
6. Bridge of the Americas (BOTA), El Paso,
7. Camino Real International Bridge, Eagle Pass.

The tool allows the user to visualize all, individual, or multiple-selection border crossings at a time. It also presents information for the five stages of the border crossing process:

1. Long-Haul at the country of origin (Mexico)
2. Drayage at the country of origin (Mexico)
3. Border Crossing
4. Drayage at the country of destination (US)
5. Long-Haul at the country of destination (US)

Dynamic map images and road segment tables are included in the tool to show corresponding road networks per border crossing and the location of each border crossing on the southern border (See Figure 13). The information is also aggregated by the day of the week and time of day. This is important in illustrating the border crossing story in different ways.



	Stage 1	Stage 2	Stage 4	Stage 5	Average
0:00	48	32	12	58	37
1:00	44	29	56	55	46
2:00	43	33	33	54	41
3:00	42	32	28	58	40
4:00	38	36	31	63	42
5:00	43	37	48	62	47
6:00	41	29	47	60	44
7:00	46	27	48	56	44
8:00	47	30	44	58	45
9:00	50	26	35	54	41
10:00	49	27	27	56	40
11:00	48	26	26	56	39
12:00	48	25	35	56	41
13:00	48	23	29	54	38
14:00	43	26	29	54	38
15:00	44	25	34	52	39
16:00	51	28	35	53	42
17:00	48	26	31	52	39
18:00	49	24	39	53	41
19:00	43	24	34	54	38
20:00	44	23	29	54	37
21:00	44	29	35	56	41
22:00	37	28	40	57	41
23:00	45	28	34	56	41
Grand Total	45	28	35	56	41

Stages	Road Segment(s)
1	Sur
2	Libramiento Fausto Martinez
3	Exit of Toll booth in Mexico-Exit of U.S. CBP Primary
4	Industrial Blvd, Loop 480
5	Loop 480, US 57

Figure 13. Example of Output from Cross Border Fluidity Estimation Tool.

To use the tool, open the Excel file location: http://tti.tamu.edu/documents/projects/tx-freight-fluidity/cross-border-fluidity-estimator.xlsx

Then, follow the instructions shown when clicking on the desired selection of travel times, sample size, or speed. You will be able to select the border crossing or multiple crossings of interest and see the information visualized in maps and charts along with data tables to show you the border crossing time estimate by the different stages of the crossing process.

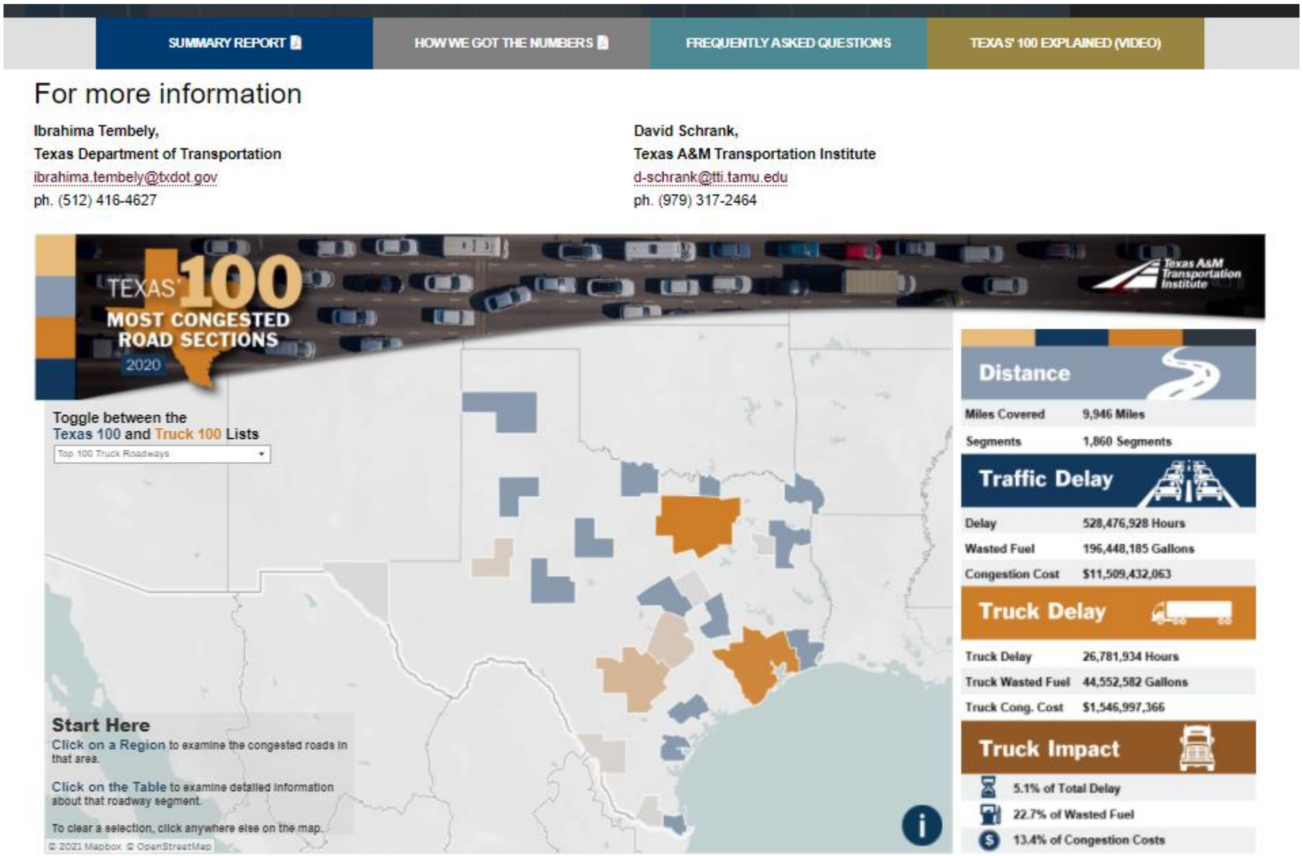
3. Fluidity in a Hurry—Back-of-the-Envelope Fluidity

While the applications discussed so far can provide defensible methods for analyzing fluidity, sometimes it is necessary to do quick assessments. For example, transportation agency leadership might ask what the top freight bottlenecks are or what is happening on a key corridor. In situations like these, the essence of fluidity analysis can be reached by employing a few different resources.

3.1 Texas Resources for Identifying the Top Freight Bottlenecks

Texas has several important resources for identifying top freight bottlenecks along corridors of interest. First is the Texas 100 for trucks. This resource was described in detail earlier, but if you want to know what the top freight bottlenecks are in the state, you can use this resource to quickly look at corridors of interest and identify bottlenecks in that geography. The related website, https://mobility.tamu.edu/texas-most-congested-roadways/, provides a web-based interface that anyone can use to see what the top roadway bottlenecks are in Texas and sort them by different performance measures. This tool allows for trucks to be assessed separately. The Texas 100 is developed yearly and incorporates traffic volume and truck probe data to populate and visualize mobility measures over 1,800 sections of road from all the Texas urban areas (Tembely & Schrank, 2020).

Using the Texas 100 (Figure 14), you can quickly rank the top bottlenecks and get a sense of annual congestion cost for these segments. You can also look through the list for a particular corridor or area of interest to see which locations experience the most congestion. Figure 15, for example, shows the top truck bottleneck segment, which is on IH 35. You can then use this information to put together details on delay and congestion cost and make some assumptions about the impacts on commodities and business. For example, if you are concerned about movement of goods from the Port of Brownsville to San Antonio, you can use the Texas 100 to look at the bottlenecks and identify which ones are on the routes in question, such as US 37 or IH 77. This information will give you a sense of bottleneck magnitude for this corridor compared to another corridor.



Rank	Road Name	From	To	Road Rank	Truck Delay/Mile	Truck TCI	Truck PTI (95th %)	Annual Truck Congestion Cost
1	IH 35	US 290 N / SS 69	Ben White Blvd / SH 71	1	98,804	2.77	5.17	$45,195,95
2	Eastex Fwy / IH 69 / US 59	SH 288	IH 10	5	63,125	2.68	4.29	$11,083,60
3	W Loop Fwy / IH 610	Katy Fwy / IH 10 / US 90	Southwest Fwy / US 59 / IH 69	2	56,717	2.49	4.01	$11,821,58
4	IH 10 / US 90	North Fwy / IH 45	Eastex Fwy / US 59	10	55,240	2.14	3.01	$5,104,66
5	Gulf Fwy / IH 45	IH 10 / US 90	S Loop E Fwy / IH 610	7	53,089	1.84	2.57	$24,319,49
6	N Loop W Fwy / IH 610	North Fwy / IH 45	Katy Fwy / IH 10 / US 90	6	50,645	2.16	3.27	$18,238,88
7	Stemmons Fwy / IH 35E / US 77	John W. Carpenter / SH 183	Tom Landry Fwy / IH 30	8	45,958	1.77	2.60	$14,607,06
8	North Fwy / IH 35W / US 287	SH 183	IH 30	16	43,826	1.86	2.62	$8,605,87
9	Bob Bullock Loop / SL 20	US – Mexico Border	IH 35 / US 83	287	41,975	1.36	1.80	$6,694,57
10	Southwest Fwy / IH 69 / US 59	W Loop Fwy / IH 610	South Fwy / SH 288	3	40,643	2.08	3.45	$12,692,94
11	IH 35	Ben White Blvd / SH 71	Slaughter Ln	12	38,368	1.76	2.82	$8,815,55

Figure 14. Example of Texas' 100 Most Congested Road Sections.

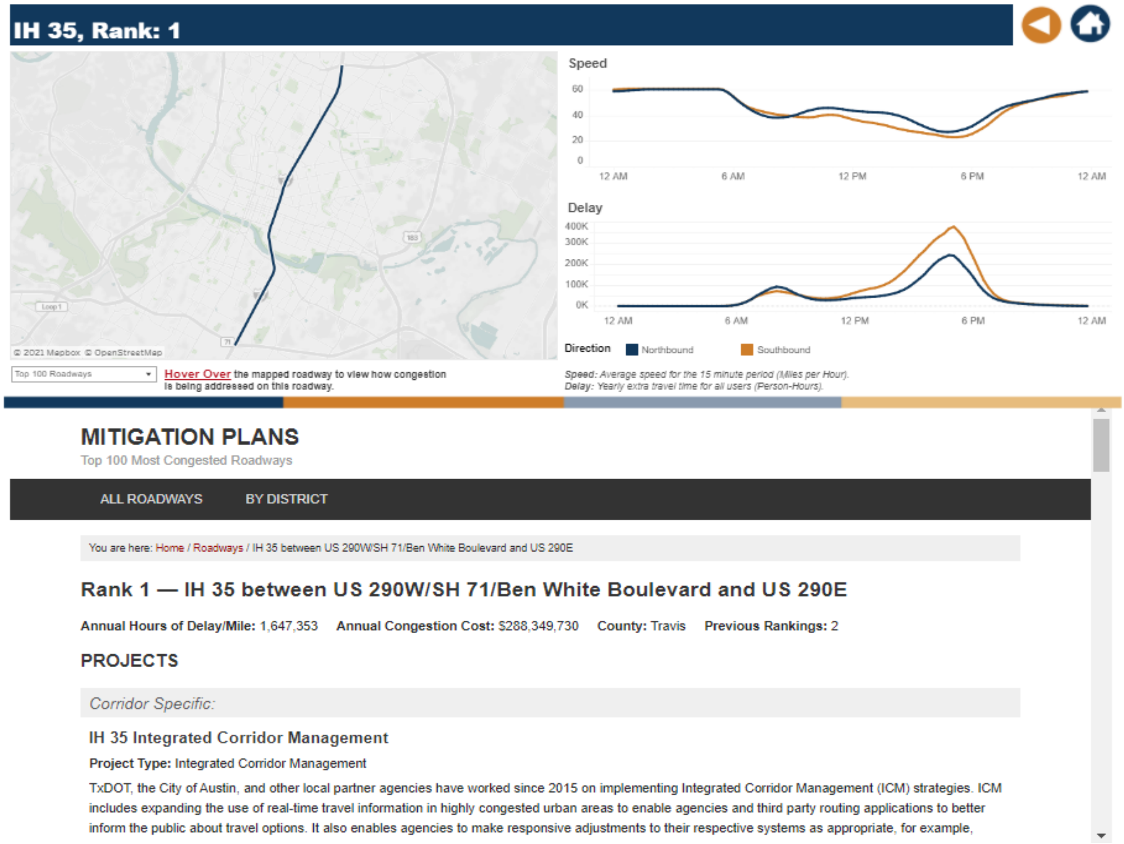


Figure 15. Texas 100 Example of IH 35, Rank 1 Truck Bottleneck Information.

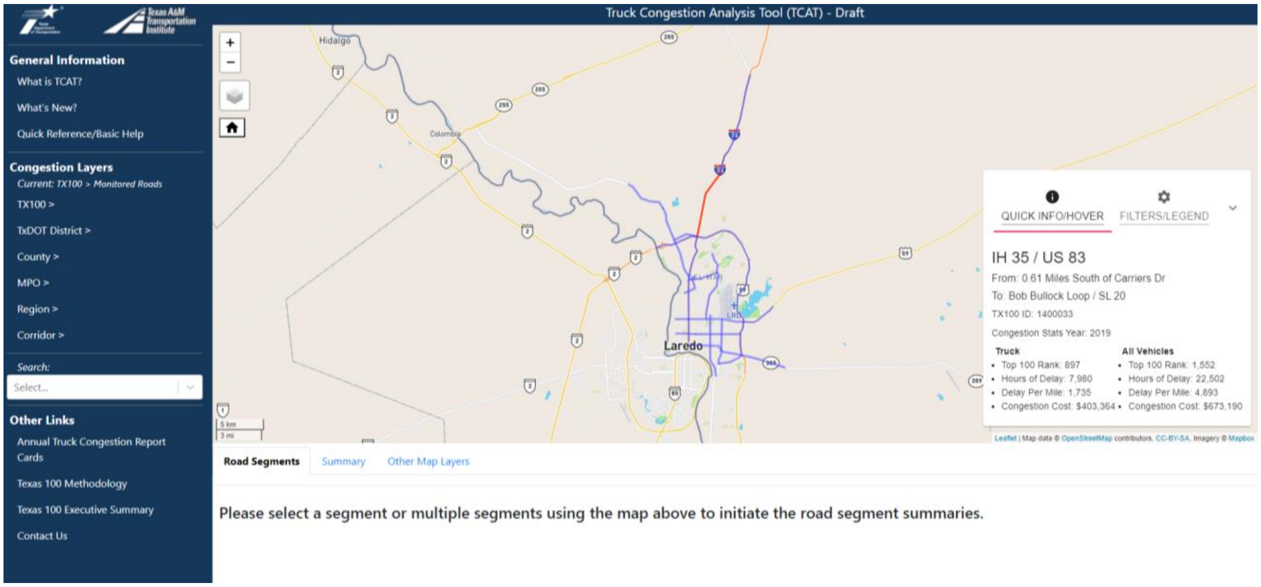


Figure 16. Truck Congestion Analysis Tool Example for Laredo Area.

Another option is to consult the TxDOT Truck Congestion Analysis Tool (TCAT). TCAT is a planning tool for analyzing and monitoring truck mobility. It provides users with access to mobility performance measures on the majority of the major roads in Texas from 2017 to the present. The mobility performance measures in TCAT are developed as part of the Texas 100 and are based on both traffic volume from the TxDOT Roadway-Highway Inventory (RHiNo) road network and INRIX traffic speed data. The tool is available at https://tcatwebprod.z14.web.core.windows.net/ (White & Wells, 2021).

For MPOs and stakeholders with congestion management process planning, performance-based planning and programming, and corridor study development roles, the Congestion Management Process Assessment Tool (COMPAT) offers performance assessment options. COMPAT uses annual averages for all Wednesdays and Saturdays from an INRIX XD speed data set procured by TxDOT to compute the Texas 100, as referenced above, and layers these data with the RHiNo network, as shown for TCAT. COMPAT offers the option to get performance summaries for MPO regions and to zoom into corridors or segments for all traffic and trucks. This tool provides robust information that can offer an area-wide summary or granular detail for a corridor of interest (White & Schrank, 2021). Figure 17 shows an example for the San Antonio area.

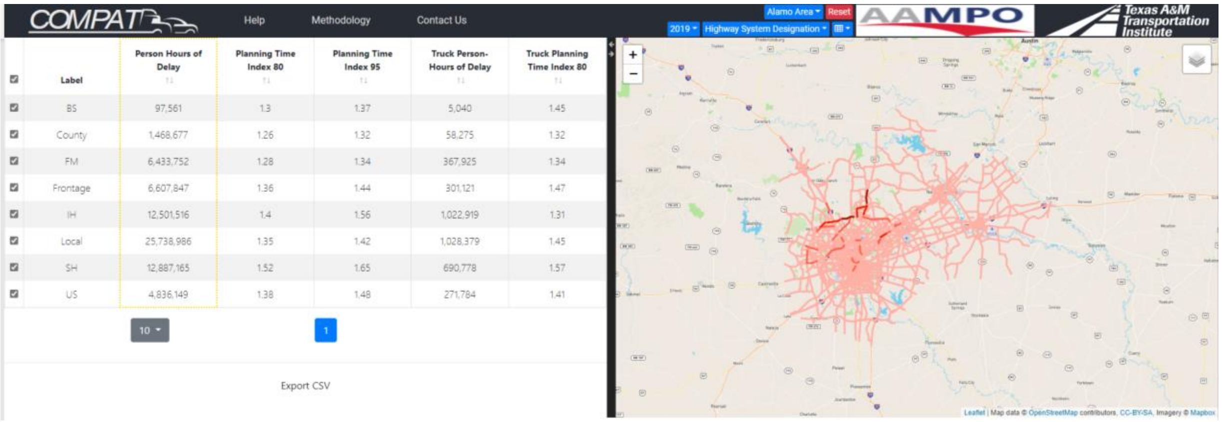


Figure 17. San Antonio Area COMPAT Example.

3.2 FHWA Freight Mobility Trends Tool

The FHWA Freight Mobility Trends Tool is an interactive dashboard with national freight statistics and freight bottlenecks on the National Highway System. There are three dashboards as part of this resource:

- National, State, and Urban Area Freight Statistics: Provides a national overview of freight measures for state, urban, and MPO areas.
- National Freight Bottlenecks: Provides a ranked list of freight bottlenecks nationally or by state and includes a separate view of the freight bottlenecks around freight facilities of airports, ports, borders, and intermodal rail.
- National Freight Commodity Corridors: Provides a corridor-level indicator of performance and visualization (Koeneman et al., 2021).

While this resource may not provide the capability to select key corridors based on commodity or supply chains, it can be used in conjunction with intel of these corridors or freight flows to assess fluidity. It is limited in that the tool was designed for national, high-level views of freight performance and does not offer Texas users granularity or local roadways they may wish to see. However, it can be used to see top bottlenecks in Texas and to understand urban, rural, and functional class type performance for major corridors and regions. This resource is available at https://ops.fhwa.dot.gov/freight/freight_analysis/mobility_trends/index.htm.

4. Concluding Ideas for Freight Fluidity

This guidebook provides methods for analyses that can help illustrate freight fluidity and provide information that you can use to think about freight from the trip perspective, the way freight customers do. While you may not perform every analysis described, each step or analysis can be useful on its own and can be incorporated into other plans and programs. For example, when determining funding priorities, looking at all bottlenecks and freight bottlenecks separately on the Texas 100 will help you make sure you are prioritizing bottlenecks that have the greatest benefits. When considering new projects or capacity expansion, knowing economic opportunities will help you think about the type of project to support current and future needs. Regardless of your role, this guidebook provides guidance for numerous ways you can understand freight trips and how fluid they are.

An important next step for freight fluidity analysis is for it to grow. First, analysis should advance from primarily looking at highway legs to working with freight stakeholders like the carriers to obtain multimodal mobility data and to build out freight fluidity analysis to show all of the trip components. Though TxDOT has made advancements in this area, continued work is needed to build true multimodal analysis and connect modal data for the entire transportation element of supply chains. Second, it is also important to develop geographical connections and understand fluidity at different geographic levels, such as regionally, mega-regionally, and internally. Third, an ultimate goal is for fluidity to evolve to real-time information that can feed freight traveler information systems and operations.

Another important step is to make freight fluidity information simple to access. While this guidebook walks you through ways to assess freight fluidity, moving the analytics into a tool that multiple users can access to see freight trip routes and their performance will be helpful. This way, the information can be used by a range of users representing different roles in transportation. This shift will also help integrate analysis into the types of visual systems used by transportation system operators who are monitoring the network in real time and build freight traveler information system communications that the state and local governments can use to better manage freight movement.

As TxDOT continues to pursue development of freight fluidity analytics and resources, visuals can be developed to illustrate fluidity and bring analytics to users through clicks or buttons with graphs and charts that can tell the freight story for Texas and its regions.

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