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16. Abstract

This report summarizes the activities performed in a one-year study with the objective to develop an understanding of the interrelationships of urban goods movement and congestion and identify performance measures that will help evaluate the impact of goods movement in the urban area. Through a survey instrument and state-of-the-practice review, this research project investigated the impacts and interactions of commodity movements within an urban area, given traffic congestion.

Researchers generally found that traditional mobility monitoring performance measures (e.g., delay, travel time index) can be adopted for freight-related mobility performance measurement. From the surveys conducted, and the state-of-the-practice review, researchers also found that 1) recurring congestion (and most typical incident congestion) is a problem that carriers/shippers can plan for, and in most cases, they can deal with congestion as it comes along; and 2) carriers/shippers tend to estimate a time cushion (buffer) into their schedules to meet their delivery times. There are times when urban congestion levels can impact freight operations (e.g., just-in-time [JIT] deliveries for manufacturing, less-than-truckload [LTL] trips by truck). Researchers also documented the interrelationship of how decisions by either the public sector or the trucking companies can influence one another.

The results of this research will be valuable to decision-making staff at metropolitan planning organizations (MPOs) and local transportation organizations to understand the big picture of local truck movements, as well as performance measures that will assist public transportation agency staff in considering freight movements and impacts in project prioritization and selection.

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DEVELOPING AND APPLYING MOBILITY PERFORMANCE MEASURES FOR FREIGHT TRANSPORTATION IN URBAN AREAS

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ABSTRACT

This report summarizes the activities performed in a one-year study with the objective to develop an understanding of the interrelationships of urban goods movement and congestion and identify performance measures that will help evaluate the impact of goods movement in the urban area. Through a survey instrument and state-of-the-practice review, this research project investigated the impacts and interactions of commodity movements within an urban area, given traffic congestion.

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EXECUTIVE SUMMARY

BACKGROUND

E-commerce, with more personalized purchasing options through the Internet, has changed distribution patterns and supply chain operations within urban areas, demanding smaller and more frequent shipments. International trade patterns have also changed recently, resulting in longer supply chains with additional last-mile trips from distribution, which impact the movement of freight in the urban areas. The combination of these factors with the increased congestion in urban areas and growing freight transportation demand decreases overall freight mobility. Freight movements contribute to overall traffic congestion in urban areas, and traffic congestion impacts regional economic development by reducing the competitiveness of freight shippers and receivers.

STUDY OBJECTIVES

The characteristics of urban goods movements vary widely by area. Some metropolitan areas have international ports of entry or maritime ports that generate substantial amounts of freight. Others have a large industrial base that attracts raw materials or semi-finished goods and generates finished products for distribution, while others are urban areas that attract finished products for consumption by the population residing in the metropolitan region.

The objective of this research project was to develop an understanding of the interrelationships of urban goods movement and congestion and identify performance measures that will help evaluate the impact of goods movement in the urban area. Through a survey instrument and state-of-the-practice review, this research project investigated the impacts and interactions of commodity movements within an urban area, given traffic congestion.

METHODOLOGY

The following five tasks were performed to satisfy the objective above:

1. **Identify State-of-the-Practice:** In this task, the research team performed a literature review to obtain information on what research has been conducted on urban goods movement, particularly in reference to freight mobility performance measurement.

2. **Develop/Administer Survey:** In this task, the research team developed a survey instrument with the intention of capturing freight movement characteristics within a selected urban area.

3. **Analyze Survey Results:** In this task, the results from the surveys were analyzed to identify any particular patterns that could provide information to define performance measures for freight movement at the urban area level.

4. **Develop Preliminary Measures:** Based on the results from the analysis of the survey and insights from the state-of-the-practice review, the research team refined existing mobility measures to satisfy public agency mobility questions.

5. **Prepare Final Report:** Finally, researchers documented the procedures and findings of the research in this task.

SURVEY DEVELOPMENT, ADMINISTRATION, AND FINDINGS

After gaining a better understanding of how the freight industry operates and what factors contribute to whether or not a freight shipment will move through a given urban environment from the state-of-the-practice review, the project team began contacting shippers and carriers in Austin, Texas, to learn about the operational characteristics of transportation companies in the region. In total, over 50 companies who transport or arrange the transportation of goods were solicited to participate in this study; however, only a small number of companies agreed to be interviewed by members of the project team.

The information collected from the stakeholder interviews allowed the project team to identify 1) what factors contribute to whether or not a shipment will move to, from, through, or within a given urban environment; and 2) how transportation companies in the Austin area operate and deal with congestion. The survey findings include:

- Carriers view congestion as a normal part of business operations. In their opinion, congestion hinders transit times, but it is typically dealt with as it is encountered, and it is expected at certain times and locations. For example, an Austin-based carrier may account for later estimated pickup or delivery times by assuming that it will take longer to get to a shipper or receiver during rush hour.

- The main concern of private companies is satisfying their customers. Shippers, receivers, and carriers are not particularly interested in average truck speeds and/or congestion, other than the fact that these things may affect fuel expenditure. These stakeholders function within the constraints of public policy and environmental factors in order to operate as efficiently as possible.

- Many shippers and receivers do not operate their own trucks. For-hire carriers are often used by these stakeholders (even the ones that operate private fleets). The primary concern of shippers and receivers is getting freight picked up from, or delivered to, their docks on time. Congestion isn’t a concern other than it may account for late pickup or delivery. Even then, most shippers and receivers believe that carriers should account for congestion when picking up or delivering their freight.

- Normal business operating hours (8 a.m. to 5 p.m.) for shippers and receivers require trucks to be on the roads during peak congestion times. Carriers have to pick up or deliver freight whenever these shippers and receivers are open.

- Congestion around intermodal freight terminals can be minimized, as demonstrated by the PierPass program (ports of Los Angeles and Long Beach); however, most freight traffic in the Austin area is not considered intermodal. A majority of the freight traffic in the Austin area can be classified as "through metro," moving north and south along Interstate 35.

- Carriers making pickups and deliveries ("within metro area shipments") in the Austin metro area typically use shorter trucks (straight trucks or 24 foot "pup trailers") as a way to more efficiently navigate urban roadways. Larger shipments, "to metro," "from metro," and "through metro" are typically transported on 53-foot trailers.

- Most of the companies interviewed as part of this project make a majority of their pickups or deliveries within 25 miles of their warehouses in the Austin area. This shows that there is enough freight originating or terminating within the Austin metro area to support the existing investment in freight terminals, warehouses, and distribution centers by private industry in the region.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made based upon this research:

1. Direct uses and applications of mobility and reliability performance measures for freight transportation in urban areas are limited in the literature. Mobility performance measure applications for typical passenger car (non-freight) travel are far more common in the literature. It appears that typical measures (e.g., delay, travel time index) used for mobility performance measurement can be adapted for freight-related mobility performance.

2. The available literature in the freight area tends to focus on mobility monitoring from the public sector perspective, rather than from the perspective of the private sector. While the public sector is generally focused on monitoring mobility for the purposes of improving the transportation system, the private sector carriers are ultimately interested in ensuring that delivery appointments can be satisfied.

3. While researchers solicited over 50 companies for an interview, only a small number of interviews with trucking companies in the Austin area were accepted. Often the interviewees indicated that they could not respond to questions about their operational characteristics because the characteristics are considered proprietary information. Low sample sizes caused by concerns of proprietary information are a relatively common occurrence in practice.

4. From the conducted surveys and the state-of-the-practice review, researchers found that:

    a. Recurring congestion (and most typical incident congestion) is a problem that carriers/shippers can plan for. They can deal with it as it comes along.

   b. Carriers/shippers tend to estimate a time cushion (buffer) into their schedules to meet their delivery times.

5. There are times when urban congestion levels can impact freight. Urban congestion can affect just-in-time (JIT) deliveries for manufacturing; it can also be especially important for less-than-truckload (LTL) traveling by local truck (e.g., FedEx, UPS) throughout the urban environment. Improving the transportation system to improve mobility and reliability for these freight operations in urban areas is valuable.

6. It follows from item #5 that mobility performance measures such as delay are valuable for monitoring the economic impacts of congestion on freight transportation. For example, from the public sector perspective, considering the economic value of the commodities delayed along a given corridor may be a valuable consideration in project prioritization and project selection.

7. As data improve, the measures/methods used for freight transportation investment decision-making will improve. Therefore, now is the time to work on developing measures and methods.

8. Researchers also documented the relationship between decisions by the public sector or the trucking companies and how they influence one another. Public agency improvements can alter trucking company operations, while carrier route changes or distribution center changes may affect congestion level. It follows that this relationship relates to the competitiveness of a particular urban area. A "friendly" freight transportation system would attract industry, creating jobs. This, in turn, would add passenger vehicles to the network.

9. This research will help the public sector understand private sector (trucking company) concerns as they relate to urban congestion. However, additional surveys/research are needed for other urban areas. An increased sample size of responses from diverse users is also desirable.

The results of this research will be valuable to decision-making staff at metropolitan planning organizations (MPOs) and local transportation organizations to understand the big picture of local truck movements, as well as performance measures that will assist public transportation agency staff in considering freight movements and impacts in project prioritization and selection.

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DISCLAIMER

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CHAPTER 1
INTRODUCTION

BACKGROUND

E-commerce, with more personalized purchasing options through the Internet, has changed distribution patterns and supply chain operations within urban areas, demanding smaller and more frequent shipments. International trade patterns have also changed recently, resulting in longer supply chains with additional last-mile trips from distribution, which impact the movement of freight in the urban areas. The combination of these factors with the increased congestion in urban areas and growing freight transportation demand decreases overall freight mobility. Freight movements contribute to overall traffic congestion in urban areas, and traffic congestion impacts regional economic development by reducing the competitiveness of freight shippers and receivers.

STUDY OBJECTIVES

The characteristics of urban goods movements vary widely by area. Some metropolitan areas have international ports of entry or maritime ports that generate substantial amounts of freight. Others have a large industrial base that attracts raw materials or semi-finished goods and generates finished products for distribution, while others are urban areas that attract finished products for consumption by the population residing in the metropolitan region.

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ORGANIZATION OF THE REPORT

This report is organized into an executive summary, five chapters, and one appendix, as described below:

Executive Summary: Provides an overview of the research and results.

Chapter 1, Introduction: Presents an introduction to the research topic, objectives, and report organization.

Chapter 2, State-of-the-Practice: Provides a discussion of key literature and provides an overview of typical freight movements.

Chapter 3, Survey Administration and Findings: Provides discussion on the survey instrument, survey administration, and findings.

Chapter 4, Discussion of Applicable Performance Measures: Discusses typical trucking operations from the perspective of the private and public sectors based upon feedback in the survey. This chapter also discusses the use of traditional mobility performance measures for project prioritization and project selection with consideration of freight.

Chapter 5, Conclusions and Recommendations: Summarizes key conclusions and recommendations from the study.

References: Lists the references.

Appendix A: Contains the survey instrument discussed in Chapter 3.

CHAPTER 2
STATE-OF-THE-PRACTICE

LITERATURE REVIEW

As part of this research effort, the project team performed a comprehensive review of published research papers to gain a better understanding of previous work conducted regarding urban mobility and its impact on freight movements. While a large number of publications exist on each of these topics separately, there is a relatively small amount of research covering urban mobility *and* its impact on freight movements. Most research concentrating on the subject of urban mobility focuses on passenger vehicles, not commercial vehicles hauling freight. The limited research that does pertain to urban freight movements concentrates on discussing how to mitigate freight congestion rather than identifying the reasons behind it. Previous work on urban mobility, specifically on performance measures for passenger vehicles and how they can be applied to commercial vehicles, is discussed at greater length in Chapter 4.

One of the most widely known efforts relating to this research is the U.S. Federal Highway Administration's (FHWA) Freight Performance Measurement (FPM) initiative. The goal of the FHWA's FPM initiative is to "help identify needed transportation improvements and to monitor their effectiveness" (*1*). FHWA is also interested in developing freight performance measures because freight movements serve as a good indicator of economic activity and can quantify traffic congestion. At present, the FHWA is monitoring travel times in freight significant corridors and collecting border crossing times at major land ports of entry (POEs) along the U.S.'s northern and southern borders as part of this program. The FHWA has also developed a Freight Analysis Framework (FAF) that models freight flow volumes in the U.S. (*2*). Data contained in the FAF are used to identify freight significant corridors in the FPM and are commonly used in a wide variety of transportation studies.

The Texas Transportation Institute (TTI) has also participated in various research projects aimed at measuring freight mobility and reliability. Research through an FHWA Pooled Fund Study developed a "Freight Box Concept" (*3,4*). The Freight Box Concept is a framework that visually incorporates the effects of geographic area, commodity type, and time period on freight mobility and reliability. It is shown in Figure 1. The Freight Box Concept is scalable to address any near-term limitations in data completeness but provides a method to communicate congestion mobility and reliability as data availability improves. This framework was designed to help transportation professionals better communicate, visualize, understand, compute, and make planning level decisions based upon the factors that affect freight reliability and mobility. As part of this work, researchers demonstrated how delay by commodity information can be used to fully incorporate freight aspects into transportation system monitoring, system evaluation, and project selection.

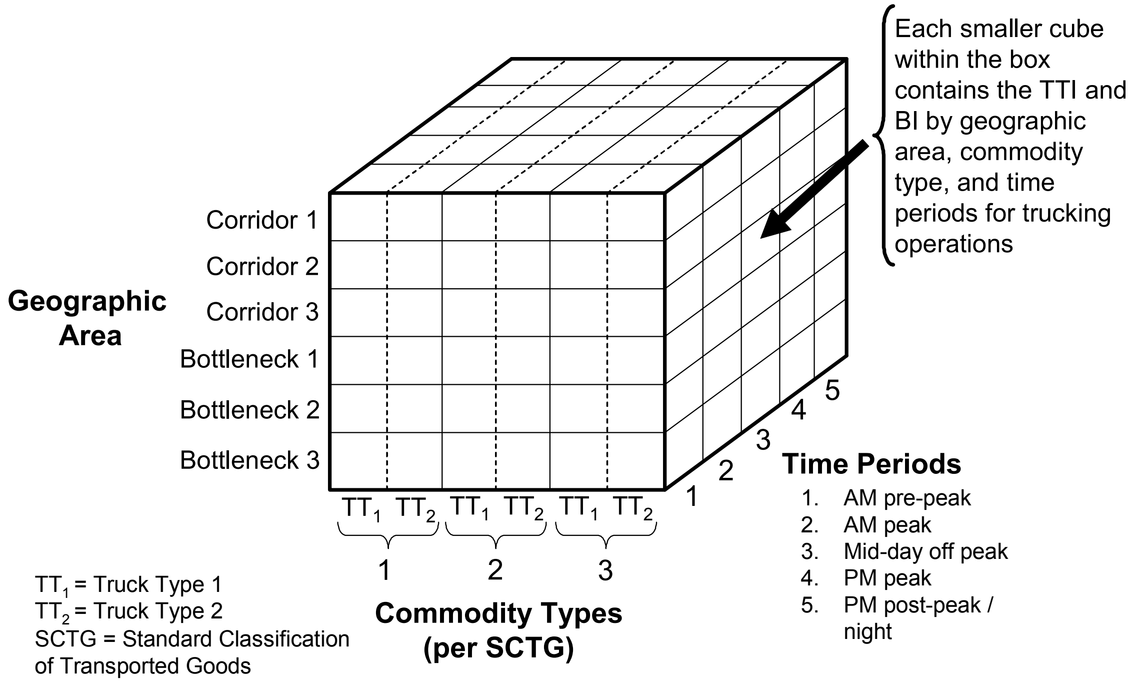

Figure 1. Freight Box Conceptual Framework Applied to Trucks (Adapted from Reference *3,4*)

One study performed by the National Cooperative Highway Research Program (NCHRP) developed a framework for defining congestion and viewing the ways in which it can affect the economic feasibility, competitiveness, and growth of economies (*5*). This study defined congestion as "a condition of traffic delay (i.e., when traffic flow is slowed below reasonable speeds) because the number of vehicles trying to use a road exceeds the design capacity of the traffic network to handle it." This study also included observations regarding how congestion affects producers of economic goods and services through three general avenues of impact: 1) availability of skilled labor, 2) cost of acquiring specialized material inputs, and 3) size of customer delivery markets. Results of these analyses illustrated that the severity of these impacts vary industry to industry, and that industries requiring skilled workers and more complex supply chains were affected significantly more by congestion than those industries that did not require those two characteristics. This project also showed that the benefits associated with operating a business in large urban areas (i.e., economies of scale) can be diminished by traffic congestion.

Another study relating to this research was performed by the Economic Research Development Group in 2008. In their paper entitled "Defining the Range of Urban Impacts on Freight and their Consequences for Business Activities," the authors analyzed three markets where local business organizations have been working with public agencies to study the economic implications of congestion growth and the economic benefits of mitigating congestion in those areas (*6*). One of the key findings of this research is that there is no universal, easy solution to combat freight delays associated with traffic congestion. Each of the three areas analyzed in this study had different freight market characteristics, and each market had to explore different solutions to improve the efficiency of freight shipments moving to, from, and within those markets.

Along with looking at published research relating to urban congestion and its impact on freight movements, the project team also analyzed studies where surveys were used in order to collect data from private carriers and logistics service providers. While there are numerous amounts of research initiatives that administer surveys to private stakeholders in the freight industry, there is one common theme in most of these studies: It is very difficult to obtain data from private companies in the freight industry. One study conducted in Australia documented the reasons why many of these problems are experienced and concluded that a lack of funding and the complexity of freight movements are the two key factors that hinder the collection of freight data (*7*). Although the study was conducted in Australia, the reasons documented in the paper mirrored many of the problems experienced by the project team in this current research effort, which are documented in the next chapter of this report.

Each of the studies included in this section of the report shed light onto the subject of urban mobility and its impact on freight movements. However, these studies, and nearly all of the studies conducted relating to this topic, look at this issue from a public agency perspective. The public perspective of urban mobility and its impact on freight movements is very different from the private industry perspective. This report seeks to highlight the differences in these perspectives and identify the gaps between them. After the gaps are identified, performance measures for urban mobility relating to freight movements that are applicable to both the public and private sectors are presented.

UNDERSTANDING FREIGHT MOVEMENTS AND PRIVATE STAKEHOLDERS

When looking at freight movements and their impact on urban mobility, it is important to understand the four different types of freight movements that take place in an urban environment. There are four basic types of freight movements in an urban environment (metro area). Figure 2 is a graphical illustration of the four types of urban freight movements.

1. "To Metro" — Trucks that have a final destination to the metro area of interest.

2. "From Metro" — Trucks that originate in the metro area of interest.

3. "Through Metro" — Trucks that travel through the metro area and have neither origin nor destination in the area.

4. "Within Metro" — Trucks that originate in, and/or are destined for, the metro area of interest. They are sometimes referred to as "local" trucks.

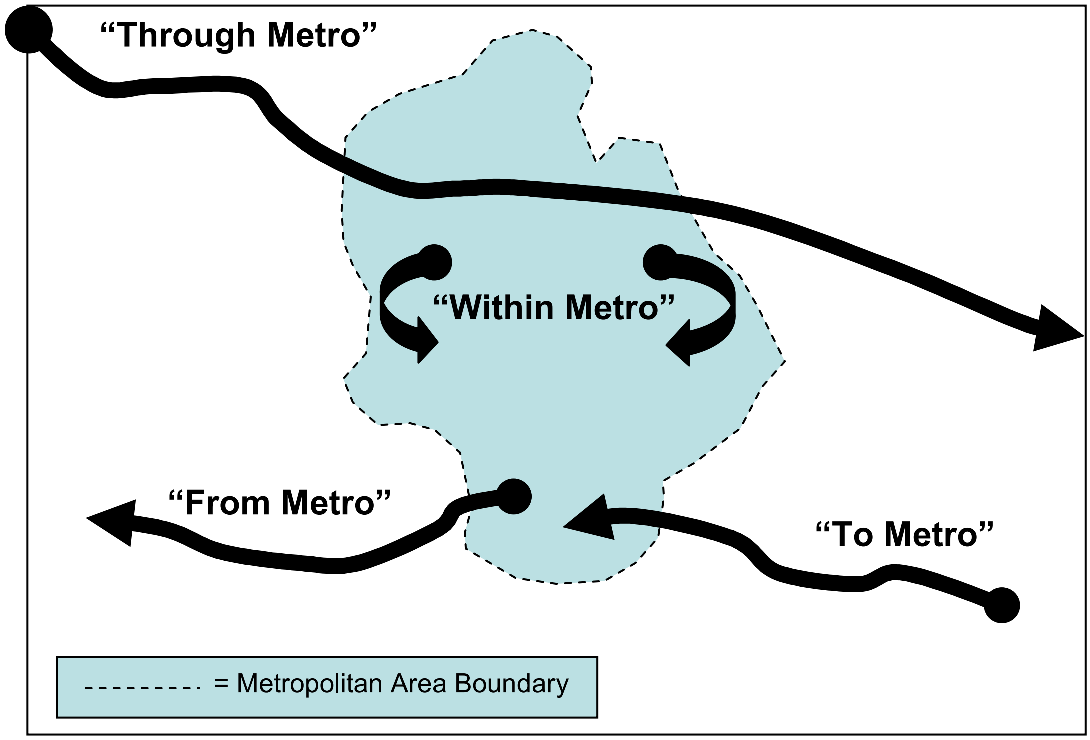

Figure 2. Illustration of the Four Common Freight Movements in a Metropolitan Area (Adapted from Reference *3*)

Along with understanding the different types of movements in a particular metro area, it is also important to understand the variety of private stakeholders involved in the logistics process. There are three basic types of private stakeholders that have an impact on urban mobility:

1. logistics service providers,

2. freight handling facilities, and

3. carriers.

These three types of private stakeholders are explained in greater detail below.

Logistics Service Providers

Typically, logistics service providers can be broken into two different categories, asset-based and non-asset-based. Asset-based companies own physical equipment that is used to transport cargo, while non-asset-based ones do not own any such equipment. Non-asset-based logistics service providers contract asset-based carriers to perform supply chain functions for them. To put it simply, logistics service providers line up carriers who have available equipment and are willing to travel from one location to another with customers who are looking to move freight between those same two locations. Logistics service providers are most often non-asset-based, but some third-party logistics providers, intermodal marketing companies, and freight forwarders may own small amounts of equipment. The most common types of logistics service providers that operate in an urban environment are:

- third-party logistics providers (3PLs),
- intermodal marketing companies (IMCs), and
- freight forwarders.

These logistic service providers act as carriers by contracting many different asset-based carriers to haul freight for them on a load-by-load basis. The many different companies that non-asset-based logistics service providers contract are commonly referred to as their carrier network. Each of these logistics service providers are discussed in further detail below.

Third-Party Logistics Provider (3PL)

A 3PL is a company that provides outsourced transportation and logistics services to companies for part or sometimes all of their supply chain management function. 3PLs typically do not own any trucks, trains, airplanes, or other type of transportation equipment. They simply contract carriers in order to meet their customers' transportation needs. 3PLs act as "transportation brokers" by lining up available carriers with available loads. They offer multiple modes of transportation and can route freight based on their customers' needs. 3PLs offer any number of logistics services, such as cross-docking, warehousing, and customs brokerage services.

Intermodal Marketing Company (IMC)

An IMC acts like a 3PL but specializes in coordinating intermodal shipments instead of a broad array of transportation services. "Intermodal" is defined as movement of containers (20-foot, 40-foot, 48-foot, and 53-foot) on a rail car. Intermodal shipments are very complex and involve using at least three separate carriers for one move (origin dray, rail carrier, and destination dray). Like most 3PLs, IMCs do not typically own any trucks, trains, or containers. They contract drayage carriers, rail carriers, and container leasing companies to perform transportation services on a shipment-by-shipment basis and charge their customer for one seamless move.

Freight Forwarder

Typically, freight forwarders are non-asset-based companies that arrange transportation services through asset-based carriers for their customers. Some freight forwarders do own their own trucks for making local pickups and deliveries. Freight forwarders act like 3PLs but tend to specialize in international shipments. Because of their international expertise, freight forwarders also prepare and process all necessary documentation for international shipments. This documentation may include commercial invoices, export declarations, or any other paperwork required by a carrier or country of export, import, or transshipment.

Freight Handling Facilities

Freight handling facilities include all of the points in a supply chain where freight is physically "touched" at any point during its transport. Shippers, receivers, distribution centers, and freight terminals are the most common examples of freight handling facilities that are located in most urban environments. A description of each of these private stakeholders can be found below.

Shipper

A shipper is the location where a freight shipment originates. Manufacturers/producers are common examples of a shipper. Shippers, however, do not technically have to produce a good that is destined for transport. At a minimum, shippers are responsible for packaging, labeling, and sending a product to another facility in a different geographic location. For example, a manufacturer of automobile parts is an example of a shipper, as it produces components used in the assembly of automobiles and sends those components to the ultimate automobile assembly plant(s). However, distribution centers (see description below) can also act as shippers, as they constantly send truckloads of product that are destined for the retail outlets that the distribution center services. This particular distribution center is not producing any product; however, for those shipments moving from the distribution center to the retail outlets, the distribution center acts as a shipper.

Receiver

A receiver is the opposite of a shipper in that a shipment terminates at a receiver's facility. Manufacturers/producers can also be considered receivers, as they must somehow receive raw materials at their facilities in order to produce whatever products they manufacture. To be considered a receiver, a company must sign for the goods after they arrive at their facility. The automobile assembly plant referenced above would be an example of a receiver.

Distribution Center

Distribution centers are most often large warehouses where freight is stored. Typically, no manufacturing or other business processes take place at these facilities. Distribution centers act as both receivers and shippers, as they accept goods into their warehouse for storage and send them to another facility once they are needed. The retail industry commonly uses distribution centers as a way to control inventory at a central location rather than store that inventory at individual retail outlets. Wal-Mart may be the best example of a retailer that uses distribution centers in the design of its supply chain.

Freight Terminal

Freight terminals are similar to distribution centers in that they act as both shippers and receivers. However, freight terminals are most often owned by a freight carrier. Freight terminals are utilized by carriers as a way to make their operations more efficient. At a freight terminal, carriers can "drop" a trailer (store it at a secure location) until they have the capacity (an available tractor) to send it to its final destination (the receiver). Freight terminals are also used to consolidate shipments with similar geographic destinations into one trailer. This practice is commonly referred to as "cross-docking." LTL carriers use freight terminals in order to perform all of the functions listed above and use a network of freight terminals to increase the efficiency of their operations.

Carriers

Carriers are the stakeholders involved in the logistics process that are responsible for physically moving a freight shipment from a shipper to a receiver. Carriers that have an impact on urban mobility are those that move shipments over the road (OTR) with tractors and trailers. There is a wide variety of OTR carriers in an urban environment, including long-haul, short-haul, LTL, small parcel, and drayage carriers. Cartage agents can also be considered as a type of carrier that has an impact on urban mobility. Each of these different types of carriers is described in greater detail below.

<u>Long-Haul Carriers</u>
Long-haul carriers are typically utilized to move freight shipments over a distance of 200-300 miles. These carriers use 48’ or 53’ trailers to move full truckload shipments from shipper to receiver.

<u>Short Haul Carriers</u>
Short-haul carriers, like long-haul carriers, move full truckload shipments in 48’ or 53’ trailers. However, short-haul carriers do not typically move shipments in excess of 200 or 300 miles. Short-haul carriers are also commonly referred to as regional carriers.

<u>Less-than-Truckload (LTL) Carriers</u>
LTL carriers specialize in picking up and delivering smaller-sized shipments that do not fill up traditional 48’ or 53’ trailers. They consolidate shipments with similar geographic destinations to fill up a trailer for greater operating efficiency. LTL carriers pick up, consolidate, and deliver shipments using a network of freight terminals. LTL carriers commonly use 48’ and 53’ trailers to move shipments between freight terminals and to pick up and deliver freight at facilities that can handle larger-sized trailers. However, they often use 24’ trailers (commonly called pup trailers) and smaller box trucks to make pickups and deliveries in urban environments where space limitations may be present.

<u>Small Parcel Carriers</u>
Small parcel carriers act similarly to LTL carriers in that they use a network of terminals to coordinate shipments between shippers and receivers. However, small parcel carriers typically transport letters and packages that are too small to move on pallets. Small parcel carriers may use air, rail, or OTR modes to transport long-haul shipments between terminals; however, they typically pick up and deliver shipments using box trucks or vans in an urban environment.

<u>Drayage Carriers</u>
Drayage carriers are those carriers that are responsible for picking up and delivering rail and ocean intermodal freight containers. Because ocean and rail carriers cannot access freight handling facilities outside of a port or rail yard, trucks must be used to deliver intermodal containers to their final destination. Once an intermodal container arrives at a port or rail facility, it is placed on a chassis (a frame with wheels) so it can be delivered to the receiver. The opposite is also true for shipments originating near a port or rail yard. Empty intermodal containers are stored at the port or rail yard on a chassis so they can be used to pick up freight shipments in the geographic area surrounding the port or rail yard. Once the container is loaded

with freight, it is taken off its chassis and put onto a container ship or freight train. Ocean intermodal containers are either 20’ or 40’ in length, while rail containers are typically 48’ or 53’ long. Additionally, 20’ or 40’ containers can be transported via rail, as sometimes it is necessary for ocean carriers to reposition equipment from the east coast to the west coast of the United States.

Cartage Agents

Cartage agents mostly operate within a very small geographic area (city or metro), using box trucks or cargo vans to move small, time-sensitive shipments. Cartage agents typically specialize in moving freight shipments to and from an airport. Because of the time sensitivity of most air shipments, a cartage agent must be able to pick up freight from an airport immediately after the cargo arrives or deliver cargo to an airport before an airplane departs. Traditional 48-foot and 53-foot trailers cannot move quickly enough in an urban environment to make these kinds of pickups and deliveries. Cartage agents are also commonly used to pick up and deliver “cross-town shipments,” or those shipments that both originate and terminate within a metro area.

Table 1 summarizes the differences between the carriers described in this section of the report and gives examples of carriers in each category.

Table 1. Carrier Type Summary

	Typical Characteristics			
Carrier Type	**Trip Length**	**Trailer Size**	**Amount of Product Moved**	**Examples**
Long-Haul	Greater than 200-300 miles	48’ and 53’	Full truckloads	• Schneider National • J.B. Hunt • Swift Transport
Short-Haul	Less than 200-300 miles	48’ and 53’	Full truckloads	• Regional or local trucking outfits • Long-haul carriers can also move short-haul trips
LTL	Any distance	• 48’ and 53’ (terminal to terminal) • 24’ (for local p/u and delivery)	1 to 10 pallets	• YRC • R&L Carriers • Saia Motor Freight • Con-Way
Small Parcel	Any distance	• 24’, 48’, and 53’ • Straight trucks and box vans for local p/u and delivery	• Less than 1 pallet • Letters and packages	• UPS • Fed Ex • DHL
Drayage	Less than 150 miles	20’, 40’, 48’, and 53’ intermodal containers	Full containers	• Start Trucking • Stevens Transport • Roadlink
Cartage	Less than 50 miles	• Straight trucks • Cargo vans	1 to 5 pallets	• CEVA • BAX Global • Mach 1 Transport

Table 2 is a representation of each of the stakeholders involved in the freight movement process in an urban environment and the types of freight movements they are most commonly involved in. There are some cases where one of these stakeholders may participate in a certain type of metro area movement for an exceptional circumstance, but that type of shipment is not commonly employed by the stakeholder in ordinary business practices.

Table 2. Metro Area Freight Movements Employed by Private Stakeholders

		To Metro	From Metro	Through Metro	Within Metro
Logistics Service Providers	3PL	✓	✓	✓	✓
	IMC	✓	✓	✓	✓
	Freight Forwarder	✓	✓	✓	✓
Freight Handling Facilities	Shipper	✓	✓		✓
	Receiver	✓	✓		✓
	Distribution Center	✓	✓		✓
	Freight Terminal	✓	✓	✓	✓
Carriers	Long-Haul	✓	✓	✓	
	Short-Haul	✓	✓	✓	✓
	LTL	✓	✓	✓	✓
	Small Parcel	✓	✓	✓	✓
	Drayage	✓	✓		✓
	Cartage Agent				✓

Shipment Routing

Before looking at the impacts of freight movements on urban mobility, it is important to understand the factors that influence whether a shipment moves to, from, through, or within an urban environment. Obviously, the shipper and/or receiver will necessitate whether or not a freight shipment will move through a given city. However, exactly how a shipment will move from a shipper to a receiver is most often determined by the payer of the freight bill for that particular shipment. The payer of the freight shipment is typically agreed upon in the terms of sale for the products or goods that are being transported and will be listed on the bill of lading (BOL), which contains all relevant information for the shipment. There are three basic billing categories that a freight shipment can fall under, each of which is described below.

Prepaid
Any BOL marked "prepaid" signifies that the shipper will be paying the freight costs.

Collect
A BOL marked "collect" indicates that the receiver will be paying for the freight costs.

3rd Party (Prepaid)
On a "3rd party prepaid" shipment, the carrier collects freight charges from an entity that is not the shipper or the receiver. The 3rd party paying the carrier is most often a 3PL or other logistics service provider who in turn charges its customer (the shipper, receiver, or whomever else asks the provider to coordinate the shipment) for the move.

These categories of freight billing methods only apply to those shipments being carried by a for-hire carrier. In the case of a shipment moving by a private fleet—the shipper or receiver may own its own trucks—the owner of the private fleet incorporates the transportation costs into the terms of sale or the carrier's own operating costs. It is important to understand who will be paying for a shipment because this factor will ultimately determine both the carrier and the mode of transport for a particular shipment, which will impact whether or not the shipment moves in an urban environment.

CHAPTER 3
SURVEY ADMINISTRATION AND FINDINGS

STAKEHOLDER INTERVIEWS

After gaining a better understanding of how the freight industry operates and what factors contribute to whether or not a freight shipment will move through a given urban environment, the project team began contacting shippers and carriers in Austin, Texas, to learn about the operational characteristics of transportation companies in the region. In total, over 50 companies who transport or arrange the transportation of goods were solicited to participate in this study; however, only a small number of companies agreed to be interviewed by members of the project team. A copy of the interview that was administered to these companies can be found in Appendix A. Key findings from the interviews are documented in this section of the report.

Each company interviewed as part of this project has some sort of facility in the Austin area for the storage of freight (freight handling facility). The sizes of the facilities range from 1,000 square feet to 900,000 square feet, and the companies employ from 2 to 84 people. A majority of these facilities operate 24 hours per day during the business week, with some facilities limiting operating hours on the weekend. Because these companies have warehousing facilities in the Austin area, they have trucks picking up or delivering freight as part of their normal operation. The number of trucks operating out of the sample ranged from 3 to 35.

A majority of the trucks operated by each sample company can be classified as "straight trucks" (approximately 20 feet in length). Fifty-three foot trailers are also used by most of the companies interviewed as part of this study, mostly for long hauls. One of the companies interviewed operates vacuum and tank trucks, as the company interviewed specializes in the transportation of liquids. The average amount of miles driven each day per truck in the sample range from 75 to 200. One of the companies interviewed also has regular runs to Dallas, during which a driver will drive 500 miles on a truck per shift.

Of the companies surveyed, a majority of the truck trips to and from the warehouses in the Austin area originate or terminate within 25 miles of each facility. Most of the inbound trucks to the facilities in the Austin area arrive overnight (between 9 p.m. and 6 a.m.) or sometime in the morning before noon. For outbound trucks, some of the sample have a set schedule for outbound trailers, and most of the sample indicated that they try to get all outbound trailers off the docks overnight or early in the morning.

There was a wide variety of commodities hauled by each company that was surveyed as part of this project. The most common commodities hauled by the sample included:

- general consumer goods,
- telecommunications equipment,
- computer/electronic equipment,

- produce/other food products, and
- mail.

Regarding congestion in the Austin area, none of the companies that were surveyed as part of this project had a clear definition of congestion. One company referred to congestion as anything that impedes delivery to a customer, while another "assumed" that congestion was traffic moving at 10 to 20 miles below the posted speed limit on a given roadway. None of the companies that were surveyed forbid their drivers from operating on any specific roadway due to congestion; however, several interviewees indicated that certain roadways at certain times of day were not used by their drivers. These roadways included:

- I-35 (throughout the Austin metro area) between the hours of 3 p.m. and 6 p.m.,
- Highway 360 around 5 p.m., and
- Mopac Freeway around 5 p.m.

Interviewees generally stated that it was up to the driver on a particular shipment to determine the most efficient way of reaching his or her destination. One company, however, had set routes that the drivers must follow and factored in extra times for the trips that were transported during rush hour. There was no formula for calculating the extra time that is factored into these rush-hour trips. For example, one carrier responding to the survey assumed that rush hour on I-35 would cost them an extra two hours of transit time for a shipment going north on the freeway.

As far as the use of toll roads go, none of the companies surveyed prohibited their drivers from using toll roads. Most of the survey sample used toll roads every day. However, some indicated that their drivers do not use toll roads because they know alternate routes that run parallel to the toll roads in Austin, and bypassing the toll roads can save money for the driver/company in the long run.

SURVEY LIMITATIONS

Typically, it is difficult to solicit the participation of private industry for a research study, and this project is no exception. As mentioned previously, a large number of companies in the Austin area were contacted to see if they would participate in this study, but only a small number agreed to be interviewed. The project team attributes the difficulty in obtaining permission from potential interviewees for this study to three factors, each of which is described below.

<u>Factor # 1: The potential interviewee is not authorized to speak on the company's behalf.</u> Often, when asked to participate in this study, a potential interviewee would indicate that he/she was not allowed to answer questions relating to the company's operational characteristics. Operational characteristics are often considered proprietary information, which is information that is highly guarded by all private companies. For this reason, this type of information is typically not shared by private companies even when confidentiality is guaranteed (which was the case in this study).

Factor # 2: The potential interviewee does not have enough information to accurately answer the interview questions. The interview questions for this study covered a wide variety of operational characteristics ranging from facility size to commodities transported/shipped to routing descriptions. For most large transportation companies, separate departments are responsible for each of these components of day-to-day operations. Because of this, it was difficult finding one person in a company that could answer all of the questions from the survey that was designed for this project.

Factor # 3: The potential interviewee does not have the time to be interviewed. The transportation industry is fast paced, and often a potential interviewee would simply say that he/she did not have the time to be interviewed for this project. In the current economic climate, there is a large amount of pressure on transportation companies to meet all of the demands of their clients so that no business is lost. This requires these companies to use all of their people and resources as efficiently as possible, especially when most transportation companies could now be considered understaffed. Therefore, although some potential interviewees expressed that they would like to help answer the project team's questions, most stated that they were unwilling to participate because of time constraints.

Although the survey sample was relatively small due to low response rates, the project team was able to gain some valuable anecdotal insights into the characteristics of transportation companies operating in the Austin metro area. Knowing how these companies operate is the first step in formulating performance measures for freight shipments being transported in a given urban environment.

FINDINGS FROM STAKEHOLDER INTERVIEWS

The information collected from the stakeholder interviews allowed the project team to identify 1) what factors contribute to whether or not a shipment will move to, from, through, or within a given urban environment; and 2) how transportation companies in the Austin area operate and deal with congestion. The survey findings include:

- Carriers view congestion as a normal part of business operations. In their opinion, congestion hinders transit times, but it is typically dealt with as it is encountered, and it is expected at certain times and locations. Any plans for congestion are formulated from past experiences. For example, an Austin-based carrier may account for later estimated pickup or delivery times by assuming that it will take longer to get to a shipper or receiver during rush hour.

- The main concern of private companies is satisfying their customers. Shippers, receivers, and carriers are not particularly interested in average truck speeds and/or congestion, other than the fact that these things may affect fuel expenditure. These stakeholders function within the constraints of public policy and environmental factors in order to operate as efficiently as possible.

- Many shippers and receivers do not operate their own trucks. For-hire carriers are often used by these stakeholders (even the ones that operate private fleets). The primary concern of shippers and receivers is getting freight picked up from or delivered to their docks on time. Congestion isn't a concern other than it may account for late pickup or delivery. Even then, most shippers and receivers believe that carriers should account for congestion when picking up or delivering their freight.

- Normal business operating hours (8 a.m. to 5 p.m.) for shippers and receivers require trucks to be on the roads during peak congestion times. Carriers have to pick up or deliver freight whenever these shippers and receivers are open.

- Congestion around intermodal freight terminals can be minimized, as demonstrated by the PierPass program (ports of Los Angeles and Long Beach); however, most freight traffic in the Austin area is not considered intermodal. A majority of the freight traffic in the Austin area can be classified as "through metro," moving north and south along Interstate 35.

- Carriers making pickups and deliveries ("within metro area shipments") in the Austin metro area typically use shorter trucks (straight trucks or 24 foot pup trailers) as a way to more efficiently navigate urban roadways. Larger shipments, "to metro," "from metro," and "through metro" are typically transported on 53' trailers.

- Most of the companies interviewed as part of this project make a majority of their pickups or deliveries within 25 miles of their warehouses in the Austin area. This shows that there is enough freight originating or terminating within the Austin metro area to support the existing investment in freight terminals, warehouses, and distribution centers by private industry in the region.

CHAPTER 4
DISCUSSION OF APPLICABLE PERFORMANCE MEASURES

FREIGHT TRANSPORTATION OPERATIONS AND ECONOMIC CONCERNS

From the state-of-the-practice review and the limited survey results obtained as part of this study, researchers have identified two key findings related to carriers and shippers and congestion impacts. These findings are:

1. Recurring congestion (and most typical incident congestion) is a problem that carriers/shippers can plan for. They can deal with it as it comes along.

2. Carriers/shippers tend to estimate a time cushion (buffer) into their schedules to meet their delivery times.

The biggest influence on carrier and shipper operations is the delivery appointment (i.e., when carriers/shippers are contracted to deliver the goods). The delivery appointment is the most important concern for those sending, carrying, or receiving freight. Missing the appointment can mean that additional costs might be incurred (e.g., overnight stay, impact on truck/trailer logistics, new contract required for delivery).

Trucking companies, and logistical operators, are accustomed to making real-time decisions in the course of typical operations. They understand that the environment and/or situation can change quickly (e.g., a truck breaks down). Urban congestion becomes one additional operational issue that must be handled. If/when congestion occurs, the focus remains on the delivery appointment: *Can I still get my goods delivered at the assigned delivery appointment time?* If not, alternatives must be investigated (e.g., identifying the route of quickest delivery, contacting the receiver to see if he/she will accept it late). The key is that truckers and receivers constantly adapt to the real-time situation as it unfolds.

The trucking and related logistics industry is very fluid to react to real-time operational changes. Because of this, the focus and urgency tends to stay on "today" rather than planning too far into the future. The near-term delivery appointment is crucial.

The Bottom Line—Saving Money

The trucking and logistics industry is focused on the bottom line. Trucking companies make money only if their trucks are moving. They care most about those factors that can save them money. Related to congestion, these "costs" include:

1. *Fuel cost:* Being stuck in congestion can increase fuel costs.

2. *Understanding the operational impact ("cost") of the lost time in congestion:* For example, if the congestion is going to last three or more hours, will the company still make the delivery appointment? If not, can the truck still get unloaded? Will the cargo be damaged? Will additional costs be incurred?

A GLIMPSE INTO TRUCKING OPERATIONS—HOW CONGESTION IMPACTS THE PUBLIC AND PRIVATE SECTORS

Because the survey results clearly illustrated that the bottom line for trucking companies is saving money, the authors wanted to expand on "typical" trucking operations, how delay is important, and how this is interpreted drastically differently by both the public sector and trucking companies. This section assists in providing this perceptive for the reader.

The "Toy Story"

Consider that your son or daughter wants the latest toy on the market. You rush to the toy store to buy the coveted toy. With luck, the toy is on the shelf, and you can make your son or daughter very happy.

Now, consider the trip that the toy has taken. Consider the supply chain that allowed that toy to be on the shelf. Within the context of this project, also consider how transportation system influences (e.g., congestion) may have affected the supply chain of this toy getting to the shelf. Consider:

- What role does delay play?
- How is delay perceived differently by the public and private sectors?
- What are the impacts to different stakeholders?

These are but a few questions that will be investigated in the following discussion.

Figure 3 shows a complete supply chain from the originating overseas factory to your local toy store. There are many steps in the supply chain. The assembled toy is loaded into a container, which is transferred by truck to the originating port. From the origin port, it is transported by ocean vessel to the destination port. At the destination port, the container of toys is off-loaded and placed on a truck for transport to the origin rail ramp, where the container is taken from the truck and placed onto a train. The container of toys is taken off the train and again placed on a truck chassis for transport to a distribution center operated by the ultimate retailer of the toy.

Most large retailers use distribution centers as a way to increase the efficiency of their supply chain. At a distribution center, inventory can be consolidated and warehoused until an individual retail outlet needs the product. When an individual retail outlet needs to re-stock its shelves with the toy, an over-the-road truck shipment is arranged to transport the toy (along with any other products the retail outlet may need at that particular time) from the distribution center to the final receiver (consignee) of the product (which in this case is a retail outlet/store). Even in this relatively simplified example, getting the toy from overseas to the local toy store involves, at least, four truck trips, one rail trip, and one ocean vessel trip.

Some portions of all four of the truck trips shown in Figure 3 will likely occur in urban areas. It is in these urban areas where the impacts of congestion would be most notable. Public agencies typically use performance measures to monitor congestion and its impacts in these urban areas. In theory, these performance measures can also be applied to trucking operations to monitor the extent of their delay. However, delay is a relative term, and it means something totally different to the public agencies compared to private-sector trucking companies. For illustration, this example will focus on the effects of delay-causing roadway congestion.

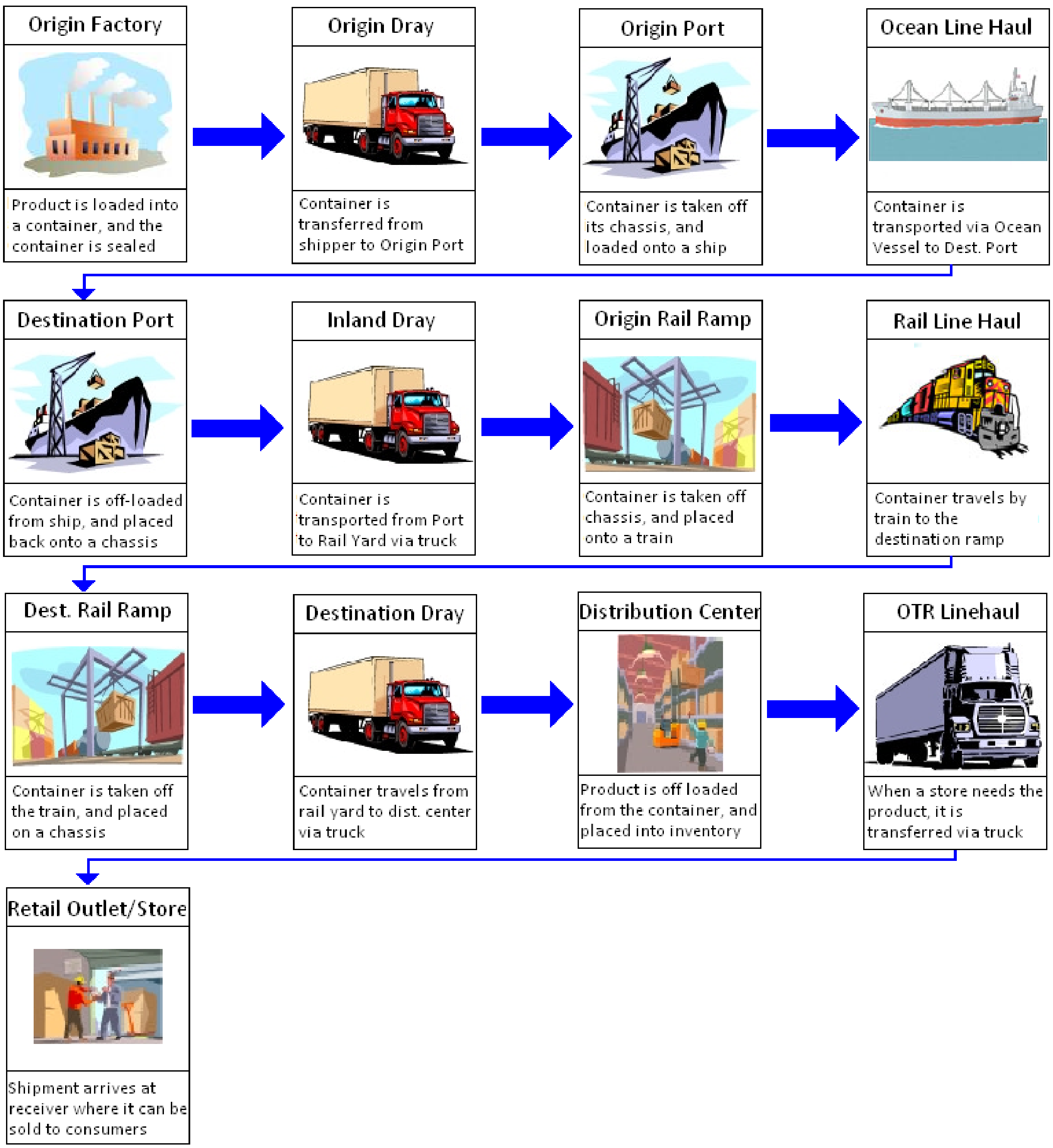

Figure 3. Supply Chain for Toy from the Overseas Factory to the Local Toy Store
(Source: Texas Transportation Institute)

The Public Agency Perspective

Figure 4 illustrates how delay-causing urban roadway congestion affects both the public sector (public transportation agency) and the private sector (trucking company). The gray highlighted area on the left of the figure relates to the perspective of the public agency. First, the roadway congestion causes personnel from the public agency to ask questions that relate to the congestion itself (e.g., how bad is the congestion?). This is typically answered in terms of travel time and delay. When faced with congestion issues, public agencies also begin to ask questions about what roadway improvements may be needed and how improvements will be programmed and funded.

Potential public agency changes include transportation system improvements. It is important to note that these public agency improvements can alter trucking company operations. The bottom dashed line in Figure 4 represents this influence. It is discussed in the next section.

Following the arrows within the public agency perspective of Figure 4 ends with identifying how stakeholders are affected. Within the public sector realm described in the figure, there are primarily two stakeholders—the motoring public and the public agencies themselves. Given these transportation improvements, the motoring public is impacted by reduced congestion and delay on the roadways of interest. The other stakeholders—public agencies—are affected in that they are responsible for continued mobility monitoring of the system, which now includes the additional transportation improvements provided in response to the initial congestion.

The Trucking Company Perspective

Along the right side of Figure 4 is the trucking company perspective on the delay-causing roadway congestion. As alluded to previously in this section of the report, the trucking industry is concerned with making delivery appointments and minimizing costs. The first question asked from the public sector perspective is whether that delivery appointment can still be made. If not, alternative roadways may be of interest. Distribution centers might also be moved if costs would be reduced. The affect of the delay on reliability is also important. There is an interest in knowing if the congestion is a “one-shot” problem or whether the road is consistently congested at the same time and place. If it is consistently problematic, there may be a long-term route-selection change needed.

From the trucking company perspective, there are no changes needed if the delivery appointments are still made, or if the current levels of congestion can be planned into the deliveries. Over the long-term, routes might be changed or distribution centers might be moved if doing so would result in lower costs (i.e., reduced fuel costs, reductions in other costs due to missed delivery appointments) relative to not changing but living with the congestion. Note that the public agency improvements can alter trucking company operations (bottom dashed line in Figure 4), and the trucking company could experience lower costs by altering trucking operations as a result of the public agency improvements.

Also note the top dashed line in Figure 4. It results because route changes or distribution center changes by carriers may affect congestion levels. For example, moving a distribution center might improve congestion in one location that is near the old location of the distribution center, while congestion might get worse near the location of the new distribution center. As shown with the two dashed lines in Figure 4, the result is a "continuous loop" where infrastructure changes by the public agencies can alter trucking company operations, and carrier route changes or distribution center changes may affect congestion levels and, therefore, influence public agency infrastructure improvement planning.

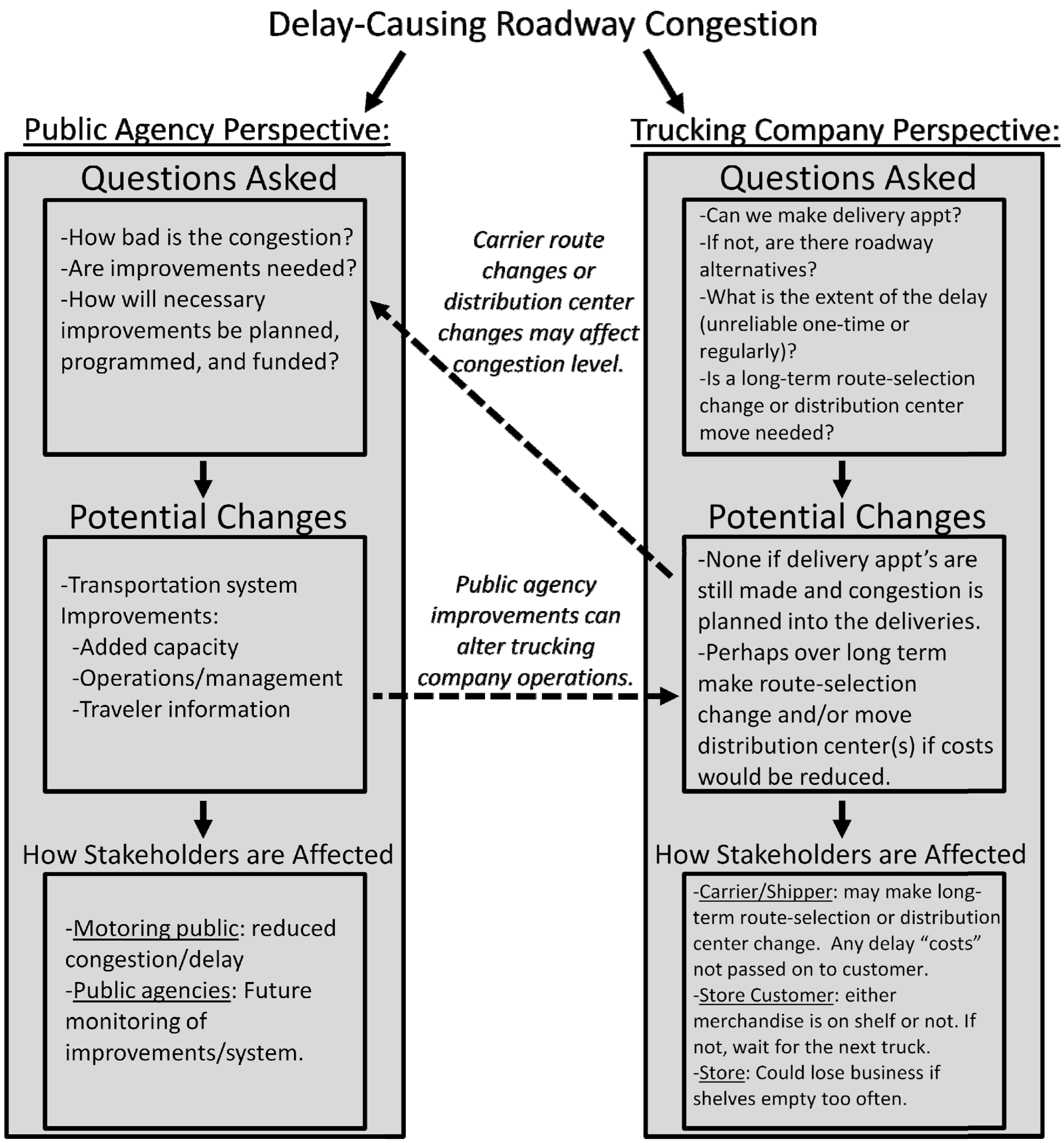

Figure 4. Public Agency and Trucking Company Perspectives on Delay-Causing Roadway Congestion

Lastly, consider how the final stakeholders are affected from the perspective of the trucking company (lower-right portion of Figure 4). The stakeholders here are the carrier/shipper, store customer, and the store itself. Carriers/shippers might make long-term route-selection or distribution center changes if costs are predictably and reliably higher along current routes than expected on an alternate route. However, any additional/unexpected costs incurred from congestion would not generally be passed along to the customer in the cost of the toy. The store customer can either find the coveted toy on the store shelf, or not. If not, the customer would likely be informed when the next truck will come. From the perspective of the store's management, it is possible that the store could lose some business if they repeatedly did not have the desired toy in stock.

Getting the Goods to the Store:
It is important to note that the supply chain shown in Figure 3 allows store management to react quickly to customer demands. For example, maybe kids are demanding blue trucks this month. If the store owners know they can get the product in three weeks based on the existing supply chain, they can put in an order. This means the goods on the rack and the shelf are much closer to what the customer wants because the store can react quicker. This equates to an improved market position for the store.

What Does This "Toy Story" Tell Us?

The public sector and private sector "see" very different effects when they experience delay-causing roadway congestion in an urban environment. The public sector is concerned with quantifying the congestion, understanding the extent of the problem, and then identifying improvements and possible funding.

The private sector (trucking company) perspective is very different. These companies begin by asking the question, "Can we make the delivery appointment?" Their focus remains on providing the service per their contract to deliver goods, and they desire to do this at a low cost. In the near-term, they are not as concerned with the extent of the congestion. Generally, they understand the transportation system as it is. They understand where bottlenecks are located in the system by time of day and location. They understand and adapt to these transportation system constraints. In some sense, it follows that trucking companies understand the current transportation system constraints so well, they may prefer operating in the known status quo without the system being changed. Referring to the bottom dashed line in Figure 4, public agency improvements can alter trucking company operations. Improvements in the system may make alternate routes more or less attractive and may alter how freight shipments flow through the transportation network.

Figure 3 shows four different opportunities for freight to move by truck. The effects of delay-causing roadway congestion as shown in Figure 4 could be experienced along any one of these four truck movements. In fact, delay-causing urban congestion could be experienced more than once along any one of these four trucking movements. The key to the private sector is that the goods still make their delivery appointments, and the private sector trucking companies plan this additional time into their schedules when initially setting the deliver appointments. For example, this can be satisfied by allowing extra days for the goods to make it to the local store from overseas. In this way, carriers/shippers already have a buffer built in to their deliveries.

The bottom line is that while a few minutes of delay for the average commuter may be important for the public sector to fix, the same few minutes for freight would not likely be significant in the grand scheme of the entire supply chain shown in Figure 4. There are many outside factors that contribute to unreliability (one of which is congestion) that are buffered into the delivery appointment times to ensure on-time deliveries.

Another way to understand this difference in perspective is to ask, “How does the trucking industry benefit from an improvement in reduced delay along a corridor?” In the near-term, if the delay is just a few minutes, it may not be significant, particularly in light of the extensive supply chain shown in Figure 3. It is possible that in the long-term, an improvement in the transportation system might make it worth the trucking company’s effort to change routes or relocate a distribution center. However, this would be a change made in the long-term with months of data, if deemed worthy at all.

Finally, the dashed lines in Figure 4 also illustrate how the decisions of the public sector influence trucking companies, and how trucking company changes can affect public agency decision-making. Public agency improvements can alter trucking company operations, while carrier route changes or distribution center changes may affect congestion level. It follows how this interrelationship relates to the competitiveness of a particular urban area. A “friendly” freight transportation system would attract industry, creating jobs. This, in turn, would add passenger vehicles to the network.

HOW THE PUBLIC SECTOR CAN ASSIST THE TRUCKING INDUSTRY—THE LINK TO PERFORMANCE MEASUREMENT

The above section described how the primary question asked by companies in the private sector when encountering congestion is whether they will make their delivery appointment. In most cases, they probably will, given the long supply chain of events (see Figure 3) and the time buffer inherently added into the delivery appointment.

Even so, there are still times when congestion levels could impact freight transportation. They can affect JIT deliveries for manufacturing, and they can also be important for LTL freight traveling by local truck (e.g., FedEx, UPS) throughout an urban environment.

Related to congestion, the following two costs were identified earlier in this report:

1. Fuel costs: Being stuck in congestion can increase fuel costs.

2. Understanding the operational impact (cost) of the lost time in congestion: For example, if the congestion is going to last three or more hours, will the company still make the delivery appointment? If not, can the truck still get unloaded? Will the cargo be damaged? Will additional costs be incurred?

Table 3 shows the relationship between these two costs and the primary trucking interests as they relate to freight congestion. Table 3 also relates these two trucking interests/concerns to what public agencies can do to address the concerns and, finally, what specific actions public agencies need to take to address each trucking concern. There are primarily three actions that public agencies can take to address each of these two concerns from the trucking industry. They are:

1. Make capacity improvements (improve roadway conditions where bottlenecks occur);

2. Add or increase operations/management (e.g., motorist assistance patrols, incident detection cameras); and

3. Provide traveler information about likely travel time and possible “worst day of a month” conditions.

Table 3. Relationship Between Trucking Interests and Public Agency Response

Trucking Interest/Concern	What Can Public Agencies Do to Address the Concern[1]	Public Agencies’ Actions to Address the Trucking Concern
Reduce fuel cost	● Make capacity improvements (improve bottleneck locations) ● Add or increase operations/management ● Provide traveler information	● Measures/procedures for infrastructure and operational prioritization/programming ● Measures/data to provide traveler information (historical or real-time information)
Understand the real-time operational cost of the lost time in congestion	● Provide real-time traffic conditions	● Measures/data to provide real-time traffic conditions

[1]Real-time traffic conditions could also be provided by private sector companies.

The Addition of a Time Buffer:
Often, the possible impact of congestion delays can be built into a driver’s schedule and an additional buffer of time can be provided by the driver to ensure the delivery time is met. If there is a known and significant freight bottleneck along one of the proposed travel routes, the driver would typically allocate additional time. However, if the driver knew that he/she might save a significant amount of fuel by going around town or avoiding a specific bottleneck, doing so could be attractive. Reducing fuel costs by maintaining constant speeds and limiting idling is probably more important than the time savings, which could be worked into the goods delivery schedule.

Per Table 3, capacity improvements could improve traffic flow if they improve bottleneck locations, which reduce truck idling. Further, providing real-time traffic conditions to the driver could facilitate decision-making to avoid bottlenecks or other incidents that could increase idling and fuel costs. Similarly, historical traffic conditions might provide trucking companies insights into transportation system performance (mobility and reliability conditions). Real-time traffic conditions from public agencies could also help trucking companies understand the real-time operational cost of the lost time in congestion by helping truckers identify if there might be a problem making the delivery appointment given existing traffic conditions. While this specific situation may have less application for long-haul truckers, it might be especially valuable for less-than-truckload operations (e.g., FedEx, UPS) delivering packages in an urban area.

Public Agency Performance Measures to Address Trucking Concerns

Table 4 takes the trucking concerns and associated public agency needs a step further by proposing performance measures and necessary data to address the trucking concerns. Decreasing idling, reducing fuel costs, and ensuring that delivery appointments are met invariably relate to performance measures that constitute a time element. Therefore, the performance measures shown in Table 4 generally relate to delay savings, travel time, and speed.

Table 4. Performance Measures and Data to Support the Measures to Satisfy Typical Trucking Interests

Public Agency Actions to Address the Trucking Concerns	Performance Measures	Data to Support the Measures
Measures/procedures for infrastructure and operational prioritization	● Travel time savings by project ● Delay savings by project	● Time savings ● Volume of cars or trucks affected ● Commodities on route that may be affected
Measures/data to provide real-time traffic conditions	● Speed by route by time of day ● Travel time by route by time of day	● Speed ● Travel time ● Traffic volume
Measures/data to provide historical traffic conditions (for planning purposes)	● Speed or travel time by location and time of day ● Travel time index ● Buffer index	● Speed ● Travel time ● Traffic volume

These measures are relatively well understood for transportation system monitoring. Their computation and application for performance monitoring are documented elsewhere (*8*). Measures for planning-level analyses such as the travel time index and buffer index are somewhat less understood than typical travel time, speed, and delay measures; therefore, they are discussed below as documented in reference *9*.

The travel time index (TTI) and buffer index (BI) are proven for measuring mobility and reliability, respectively, for passenger car travel. The travel time index is defined, as shown in Equation 1, as the peak-period travel rate divided by the free-flow speed or posted speed travel rate. Therefore, a TTI of 1.20 indicates that it takes, on average, 20 percent longer to travel in the peak than it does in the off-peak period.

$$\begin{array}{c}\textit{Travel Time Index}\\ (\textit{passenger cars})\end{array} = \frac{\textit{Peak-period travel time}}{\textit{Free-flow or posted speed travel time}} \qquad \text{(Equation 1)}$$

Obviously, truck travel is influenced by additional factors that do not affect passenger travel. Observed truck speeds are affected by not only congestion levels and time-of-day patterns, but also the urgency of the driver (i.e., an owner/operator's incentive is productivity, and he may likewise be driven to deliver more shipments, while a private company driver may be paid hourly), commodity type, weight, and truck type (size). Grade also has a larger effect than with passenger vehicles, and there may be speed restrictions that meter truck speeds.

Similarly, the free-flow travel rate for trucks is limited by some of these same conditions. The urgency, commodity, weight, truck/roadway characteristics, grade, and speed restrictions will all affect, and potentially be limits on, the free-flow speed for trucks. Equation 2 is a proposed travel time index for trucks that can reflect these subtle differences in contrast to Equation 1 for passenger cars.

$$\begin{array}{c}\text{Travel Time Index} \\ (\text{trucks})\end{array} = \frac{\text{Observed truck travel time}}{\text{Truck free-flow or posted speed travel time}} \qquad \text{(Equation 2)}$$

Equation 3 shows the buffer index equation, which estimates the extra time (buffer) needed to ensure on-time arrival for most trips. For example, a buffer index of 40 percent means that a traveler should budget 28 minutes for a 20-minute average peak trip time to ensure 95 percent on-time arrival (i.e., late one day in 20 work days per month). The BI can apply to passenger cars or trucks and, presumably, all modes of freight where there is an interest in quantifying reliability. The calculation of the BI requires a continuous data source to obtain reliability over time (e.g., day-to-day, seasonal).

$$\begin{array}{c}\text{Buffer Index (\%)} \\ \left(\begin{array}{c}\text{passenger cars} \\ \text{and trucks}\end{array}\right)\end{array} = \left(\frac{\text{95th percentile travel time - Average travel time}}{\text{Average travel time}}\right) \times 100 \qquad \text{(Equation 3)}$$

The Importance of Commodities in Prioritizing Roadway Improvements

A different set of transportation improvement projects might be chosen if freight delays are properly considered. Every year funding is made available for transportation improvement projects. It is the responsibility and expectation of public agencies to perform appropriate mobility analyses to ensure monies are allocated properly to the appropriate roadways for improvement. Historically, monitoring has been performed by evaluating passenger car congestion impacts. There is a need to distinguish between freight and passenger car travel for system monitoring, system evaluation, and project selection because freight and passenger car travel characteristics and dollar values differ. For example, research in Houston, Texas, indicated that commercial vehicle travel times were nearly 8 percent higher than vehicles instrumented with toll tags (i.e., the general traffic stream) under free-flow conditions, and 6 percent higher during congested conditions (*10*). The study was along an approximately 2-mile corridor, and over longer distances, such differences would become even more significant.

The TTI recently documented a proof-of-concept for a methodology to develop annual congestion costs for both passenger and commercial vehicles, as well as annual commodity values (*3,4*). The methodology uses speed-flow relationships used for the *Urban Mobility Report* (*11*) and commodity information from the FHWA FAF. The methodology is documented in detail elsewhere (*3,4*). Key findings of this work are discussed below as documented in references *3* and *4*.

Illustrating Delay and Cost Savings in the Public Sector
As part of the previous work performed by TTI, researchers analyzed roadway segments of a minimum distance of approximately 5 to 10 miles in length for the primary interstates and highways in Austin, Texas, and Denver, Colorado (*3,4*). Segments were divided at major interchanges, changes in geometric characteristics, or geographic boundaries.

Table 5 shows the results for a few selected roadway segments from the highways in the Austin and Denver regions. The value of the commodities moving in each roadway segment is shown as well. The value of the commodities moving in each roadway segment is far greater than the price tag for the congestion in that segment, even on the interstate highways, which have the highest average daily traffic values.

Example—Comparison of Cargo and Delay:
If a single car on I-35 in Austin with one occupant is delayed for 15 minutes on a given day, the cost of that delay will be under $4.00. If a single truck is delayed for the same 15 minutes, the cost of the delay will be about $26. However, the average value of the commodities in a single truck in Austin is approximately $12,000. This value may be even higher if a just-in-time shipment is delayed, which could lead to an assembly line shutdown. This suggests that project selection and prioritization processes should value truck delay much higher than car delay. This might shift investments toward ports, intermodal terminals, and significant freight corridors. From an economic sense, it is important to note that cars and trucks are impacted differently by congestion.

Table 6 displays the results for all the highway corridors in the Austin and Denver regions. The delay and commodity values from each roadway segment (e.g., Table 5) were aggregated to the corridor level. The delay for each corridor contains all of the delay summed from all of the segments. The annual commodity values were weighted by truck travel to obtain the corridor commodity values. Many of the trucks will travel multiple segments along each corridor, so their commodity value should not be counted more than once.

An example of the commodity level information is shown in Table 7 for two individual segments from the Denver region. This is the level of detail that is available from the Freight Analysis Framework dataset; it is the basic level of data behind the aggregated information shown in Tables 5 and 6. The value of each truckload becomes apparent from this table. For example, the average value for a truckload of alcoholic beverages is about $12,000, while the value for a chemical products truck is almost $22,000.

Improving Data Sources for Freight

While the measures for mobility and reliability discussed above are proven for passenger cars, there are currently limited adequate data for quantifying these measures for freight operations. As more improved truck travel time data (e.g., private sector truck speed observations) and commodity information become available, more accurate temporal and spatial analysis of trucking operations may be possible.

Table 5. Congestion Costs and Commodity Values for Selected Roadway Segments in the Austin and Denver Regions (Adapted from References *3* and *4*)

Roadway	Segment Length (miles)	Daily Traffic Volume	Daily Truck Volume	Annual Congestion Cost ($million)[1]		Annual Commodity Value ($mil)[2]
				Passenger	Commercial	
Austin						
I-35	9.2	200,000	24,000	106.50	29.60	95,938
US 290 E	9.6	42,000	3,360	0.56	0.16	13,175
US 209 W	3.5	45,000	2,250	0.22	0.05	7,949
US 183	8.3	120,000	2,400	22.60	1.21	8,849
US 79	4.8	28,000	5,320	0.16	0.10	17,838
Loop 1	4.7	130,000	2,600	21.37	1.14	8,613
SH 71	4.3	60,000	5,400	0.35	0.12	18,568
Denver						
I-70	4.8	105,000	9,450	6.35	1.76	45,969
I-25	5.7	190,000	11,400	49.44	10.88	56,399
I-76	4.2	75,000	7,500	5.00	1.68	27,325
I-225	5.0	115,000	8,050	44.80	9.86	27,102
I-270	6.0	80,000	10,400	9.31	3.70	33,783
C-36	6.0	80,000	3,200	9.77	1.60	10,411
US-6	5.4	120,000	4,800	11.78	1.92	14,776
C-470	9.2	90,000	5,400	26.73	5.88	17,197
C-121	5.0	50,000	1,500	11.33	1.22	5,091
US-285	8.9	60,000	2,400	28.76	4.69	7,730
C-2	3.9	56,000	1,680	7.68	0.83	5,619

[1]Annual congestion costs are for 250 days (weekdays).
[2]Annual commodity values are for 365 days per year.
See references *3* and *4* for all assumptions and related discussion.

Table 6. Congestion Costs and Commodity Values for All Highway Corridors in the Austin and Denver Regions (Adapted from Reference *3*).

Roadway	Corridor Length (miles)	Daily Vehicle-miles of Travel (million)		Annual Congestion Cost ($million)[1]		Annual Commodity Value ($mil)[2]
		Passenger	Commercial	Passenger	Commercial	
Austin						
I-35	80.1	7.23	1.54	269.6	88.2	82,270
SH-21	51.0	0.42	0.06	0.6	0.3	4,646
SH-71	61.0	1.52	0.12	22.3	4.7	9,341
US-290W	32.4	1.11	0.07	41.4	6.5	16,144
US-290E	42.6	1.00	0.11	24.4	7.8	11,362
US-79	25.6	0.48	0.11	37.5	18.6	17,582
US-183	90.3	3.26	0.21	30.8	2.9	9,909
Loop1	10.0	1.16	0.03	33.1	2.2	9,914
SH-29	35.9	0.47	0.06	0.7	0.2	5,362
SH-95	56.8	0.54	0.08	0.8	0.4	4,989
Denver						
I-70	32.0	3.16	0.37	104.6	35.6	53,594
I-25	34.0	5.42	0.50	323.5	97.4	69,206
I-76	22.3	0.97	0.17	6.3	2.2	29,134
I-225	12.4	1.34	0.10	118.5	24.7	27,717
I-270	6.0	0.42	0.06	9.9	3.7	33,783
C-36	18.0	1.47	0.07	27.3	3.7	13,427
US-6	9.9	0.92	0.04	12.9	2.0	13,326
C-470	65.7	2.72	0.22	39.5	7.4	12,000
C-121	25.5	1.13	0.04	45.2	4.9	5,350
US-85	7.3	0.22	0.03	9.0	2.8	14,033
US-285	13.8	0.67	0.03	36.5	6.0	7,444
C-7	17.6	0.32	0.02	13.1	1.7	3,304
US-40	23.0	0.71	0.03	23.6	3.0	4,544
C-2	14.2	0.52	0.02	19.8	2.6	5,093
C-88	19.1	0.74	0.03	28.2	4.3	6,061
C-30	20.4	0.58	0.02	19.5	2.7	3,993
C-95	14.4	0.52	0.02	20.7	2.1	5,633
US-287	20.3	0.69	0.03	26.1	3.3	5,401
C-128	9.9	0.17	0.01	5.0	0.5	2,887
C-72	6.4	0.15	0.01	4.9	0.9	4,543
C-93	13.6	0.25	0.02	7.6	1.2	4,798
C-391	9.4	0.36	0.01	15.1	1.5	4,212
C-177	6.4	0.20	0.01	7.3	0.7	3,596
C-44	4.9	0.07	0.01	2.0	0.2	2,336
C-22	2.5	0.02	0.01	0.4	0.1	1,749

[1]Annual congestion costs are for 250 days (weekdays).
[2]Annual commodity values are for 365 days per year.
See reference *3* for all assumptions and related discussion.

Table 7. Daily Commodity Level Breakdown for Selected Denver Roadway Segments (Adapted from References *3* and *4*).

Commodity	I-70		C-2	
	Trucks	Value ($000)	Trucks	Value ($000)
Alcoholic beverages	293	3,517	52	631
Animal feed	129	583	14	50
Articles—base metal	370	4,627	42	637
Base metals	171	2,774	20	315
Basic chemicals	147	1,116	24	137
Building stone	12	38	3	7
Cereal grains	384	308	42	32
Chemical products	158	3,437	8	265
Coal	285	120	0	0
Coal—n.e.c.	185	601	29	110
Crude petroleum	8	12	3	5
Electronics	100	9,496	7	523
Fertilizers	101	133	10	13
Fuel oils	259	815	54	165
Furniture	96	2,051	12	243
Gasoline	89	684	16	130
Gravel	913	135	167	26
Live animals/fish	52	742	13	183
Logs	26	463	3	61
Machinery	227	22,430	45	3,774
Meat/seafood	103	4,489	6	296
Metallic ores	3	69	0	12
Milled grain products	319	2,052	46	197
Misc. mfg. products	171	7,288	17	547
Mixed freight	287	14,362	44	1,853
Motorized vehicles	125	6,050	10	484
Natural sands	248	17	54	3
Newsprint/paper	19	357	0	10
Nonmetallic mineral products	1,309	2,368	334	374
Nonmetallic minerals	105	170	8	19
Other agricultural products	163	1,614	25	160
Other foodstuffs	399	5,847	58	675
Paper articles	42	975	3	72
Pharmaceuticals	21	1,454	4	207
Plastics/rubber	199	5,334	13	557
Precision equipment	368	2,489	117	243
Printed products	165	3,427	12	277
Textiles/leather	34	4,607	3	291
Tobacco products	1	112	0	48
Transport equipment	81	3,149	5	407
Unknown	358	3,388	98	923
Waste/scrap	595	510	211	159
Wood products	330	1,729	46	270
Total—Daily	9,450	125,943	1,680	15,395

See references *3* and *4* for assumptions and discussion of estimation procedures.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made based upon the research presented here:

1. Direct uses and applications of mobility and reliability performance measures for freight transportation in urban areas are limited in the literature. Mobility performance measure applications for typical passenger car (non-freight) travel are far more common in the literature. It appears that typical measures (e.g., delay, travel time index) used for mobility performance measurement can be adapted for freight-related mobility performance.

2. The available literature in the freight area tends to focus on mobility monitoring from the public sector perspective, rather than from the perspective of the private sector. While the public sector is generally focused on monitoring mobility for the purposes of improving the transportation system, the private sector carriers are ultimately interested in ensuring that delivery appointments can be satisfied.

3. While researchers solicited over 50 companies for an interview, only a small number of interviews with trucking companies in the Austin area were accepted. Often the interviewees indicated that they could not respond to questions about their operational characteristics because those characteristics are considered proprietary information. Low sample sizes caused by concerns of proprietary information are a relatively common occurrence in practice.

4. From the conducted surveys conducted and the state-of-the-practice review, researchers found that:

    a. Recurring congestion (and most typical incident congestion) is a problem that carriers/shippers can plan for. They can deal with it as it comes along.

    b. Carriers/shippers tend to estimate a time cushion (buffer) into their schedules to meet their delivery times.

5. There are times when urban congestion levels can impact freight. They can affect JIT deliveries for manufacturing. They can also be especially important for LTL traveling by local truck (e.g., FedEx, UPS) throughout the urban environment. Improving the transportation system to improve mobility and reliability for these freight operations in urban areas is valuable.

6. It follows from item #5 that mobility performance measures such as delay are valuable for monitoring the economic impacts of congestion on freight transportation. For example, from the public sector perspective, considering the economic value of the commodities delayed along a given corridor may be a valuable consideration in project prioritization and project selection.

7. As data improve, the measures/methods used for freight transportation investment decision-making will improve. Therefore, now is the time to work on developing measures and methods.

8. Researchers also documented the relationship between decisions by the public sector or the trucking companies and how they influence one another. Public agency improvements can alter trucking company operations, while carrier route changes or distribution center changes may affect congestion level. It follows that this relationship relates to the competitiveness of a particular urban area. A "friendly" freight transportation system would attract industry, creating jobs. This, in turn, would add passenger vehicles to the network.

9. This research will help the public sector understand private sector (trucking company) concerns as they relate to urban congestion. However, additional surveys/research are needed for other urban areas. An increased sample size of responses from diverse users is also desirable.

The results of this research will be valuable to decision-making staff at MPOs and local transportation organizations to understand the big picture of local truck movements, as well as performance measures that will assist public transportation agency staff in considering freight movements and impacts in project prioritization and selection.

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APPENDIX

SURVEY INSTRUMENT

Company ___________________________ Confidential Code No: ____________

1. What is the approximate square footage of your facility?

____

____

____

2. How many employees work at facility?

____

____

____

3. What hours of the day and days of the week do you typically operate?

____

____

____

4. How many vehicles does your company operate from this facility?
   Vans, Panel trucks, Semis

____

____

____

5. How many trucks come to and from your facility on an average day, what is their average weight, and what percentage operate less-than-load?

____

____

____

Type of Vehicle	Shipments TO Your Facility		
	Number of Trucks	Average Weight (lbs)	% operating LTL
Vans		Lbs	%
Panel trucks		Lbs	%
Semis – 20 feet		Lbs	%
Semis – 40 feet		Lbs	%
Semis – 53 feet		Lbs	%

Type of Vehicle	Shipments FROM Your Facility		
	Number of Trucks	Average Weight (lbs)	% operating LTL
Vans		Lbs	%
Panel trucks		Lbs	%
Semis – 20 feet		Lbs	%
Semis – 40 feet		Lbs	%
Semis – 53 feet		Lbs	%

6. How many miles does an average driver put on a truck during his/her shift?

____

____

____

7. What percentage of your outbound trucks delivering shipments are scheduled in the following ways?

____

____

____

Type of Service	Type of Truck		
	Vans	Panel Trucks	Semis – all sizes
Regular Daily Service with Routine Stops			
Regular Daily Service with Varying Stops			
Irregular Daily Service with Multiple Stops			
Irregular Daily Service with Individual Stops			
Other			
Total	100 %	100 %	100 %

8. What percentage of your inbound and outbound truck movements are destined for the following locations?

____

____

____

Length of Trips	Percentage of Truck Trips	
	Inbound	Outbound
Within 25 miles of location	%	%
Within 25-50 miles of location	%	%
Between 50-100 miles of location	%	%
Over 100 miles from location	%	%

9. What is the most common commodity shipped or received by your facility, and what percentage of total shipments does it comprise?

____

____

____

Commodity	Percent of Total Shipments
	%
	%
	%
	%
	%

10. Estimate the percentage of inbound and outbound truck movements (both goods and services) at your facility by time of day. Please consider all truck movements, whether the trucks are owned or leased by your facility.

____

____

____

Inbound

Arrival Time	6am-9am	9am-noon	Noon hour	1pm-6pm	6pm-9pm	9pm-6am	Total
Percentage:							= 100%

Outbound

Departure Time	6am-9am	9am-noon	Noon hour	1pm-6pm	6pm-9pm	9pm-6am	Total
Percentage:							= 100%

11. Are there times of the day when your drivers avoid being on certain roads? Can you provide some information for the reasons?

____

____

____

Roadway	Time	Location	Reason

12. For your business operations, how do you define roadway congestion?

____

____

____

____

____

____

13. Do your trucks use toll facilities?