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Preparing Texas' Freight Transportation System for 2055

Technical Report 0-6809-1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
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16. Abstract

Efficient, reliable, and safe freight transportation is critical to the economic prosperity of any region. An efficient multimodal and intermodal transportation system reduces transportation and supply chain transaction costs and increases connectivity, mobility, reliability, and accessibility to local and global markets. An efficient freight transportation system, therefore, supports economic development, expansion of international trade, increased employment, growth in personal income, and growth of the gross domestic product of a region—ultimately improving the quality of life of its citizens. This research documents major trends (i.e., global trade, sociodemographic, environmental, and technology trends) that could impact the future business models of Texas' companies; identifies and discuss factors that influence companies' site selection decisions and explores how Texas ranks compared to other states; discusses changing business models and the associated impacts on and expectations for a future freight transportation system, and provides insight into the foreseen role for the Texas Department of Transportation in planning for an efficient, reliable, and safe freight transportation system in 2055 that supports the growth of industry and ultimately the Texas economy. This research document is a companion to Report 0-6809-2 that explores international rail traffic increases and their potential impacts on Texas rail planning needs.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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CHAPTER 1:
INTRODUCTION

BACKGROUND

The Intermodal Surface Transportation Efficiency Act of 1991 and all subsequent funding and authorization bills that govern surface transportation spending (including the Moving Ahead for Progress in the 21st Century Act) have identified an understanding of the needs of the freight transportation sector as a critical component of transportation planning. States, however, often find it challenging to conduct freight planning. A review of the pertinent literature reveals numerous reasons for this, such as:

- An inadequate understanding of how the private sector approaches decisions involving freight movements and the perceived difficulty of working with private shippers and carriers.
- An inadequate understanding of the factors that impact the competitiveness of different freight modes operating in a region.
- The difficulty in obtaining quality freight data to analyze freight system trends, needs, issues, and performance measures required to ensure informed freight policies, strategies, and infrastructure improvements (Prozzi et al. 2011).

Although a mandated planning process guides transportation decisions, long-range transportation planning involves many difficult choices, especially in an era of constrained resources. How are demographics, economics, and freight demand likely to interact over time? Which are the most important trends to monitor? Which investments should be funded? These questions are problematic, particularly if transportation planners and policy makers must make decisions within a time horizon that extends more than 20 years into the future.

PROJECT OBJECTIVES

The Texas Department of Transportation (TxDOT) contracted with the Texas A&M Transportation Institute and the Center for Transportation Research at The University of Texas in Austin to develop a framework for an effective and efficient Texas freight transportation system four decades into the future. Specifically, the objectives of the research were to:

- Consult with a sample of companies in Texas and Mexico to identify trends that could impact future business models and their vision and expectations for a Texas freight transportation system four decades into the future.
- Develop a freight framework that TxDOT can use to support proactive freight planning in enabling a freight transportation system that meets the needs and expectations of freight stakeholders four decades into the future.

CONTENTS OF THIS REPORT

The findings of this research are documented in this report. Following this introduction, Chapters 2 through 5 explore the major trends that could impact the future business models of companies:

- Chapter 2 reviews global trade trends and factors that could impact global trade.
- Chapter 3 reviews the sociodemographic changes predicted for Texas and the potential impacts on consumer demand.
- Chapter 4 explores major environmental concerns and anticipated government, industry, and consumer responses to the identified trends.
- Chapter 5 discusses current technologies that shippers and freight carriers use (e.g., radio frequency identification [RFID] and global position systems [GPS]), services accessible to consumers that are reshaping demand for goods and services (e.g., e-commerce), and emerging technologies that have the potential to transform the supply chain (e.g., three-dimensional [3D] printing, automated vehicles, and truck platoons).
- Chapter 6 identifies factors that influence companies' site selection decisions and explores how Texas ranks compared to other states on a number of identified factors that influence a company's decision to locate in a particular location.
- Chapter 7 discusses changing business models and the associated impacts on and expectations for a future transportation system.
- Chapter 8 provides a framework for TxDOT in planning for an efficient, reliable, and safe freight transportation system in 2055 that supports the growth of industry and ultimately the Texas economy.
- Chapter 9 offers conclusions and recommendations.

This report also includes three appendices:

- Appendix A provides additional information on U.S. trade.
- Appendix B contains data on the world population and U.S. demographic trends.
- Appendix C provides the results of the interviews that were conducted with the U.S. companies, Mexican maquilas, and site selectors.

CHAPTER 2:
GLOBAL TRADE TRENDS

The TxDOT report titled *Freight Movement in Texas: Trends and Issues*, developed for the Texas Freight Mobility Plan, identifies several economic factors that have or may impact Texas trade flows. The report discusses global markets that are emerging from an evolving world economy and that impact global trade routes. The report claims that "U.S. companies are expanding into emerging markets across the world where their goods and services can be sold, accelerating the growth of their company or industry and expanding the reach of the U.S. exports" (TxDOT 2013). Another TxDOT report, *Report from the Panama Canal Stakeholder Working Group*, concludes that Texas and Texas ports are well positioned to serve existing, emerging, and growing international markets, both as a result of the Panama Canal expansion and regardless of the expansion (Turnbull 2013).

Based on these reports and other literature, this chapter examines the major global trade partners of Texas, Texas exports, and the factors that could impact global trade in the future.

TEXAS'S TRADE PARTNERS

The U.S. Census Bureau's Foreign Trade Division lists Texas's export and import trade partners. Table 1 provides the export and import trade levels, in terms of value, for Texas's top 25 trade partners in 2014. Mexico is Texas's most important trade partner with more than $192 billion in trade in 2014, representing more than 32 percent of the total Texas trade.

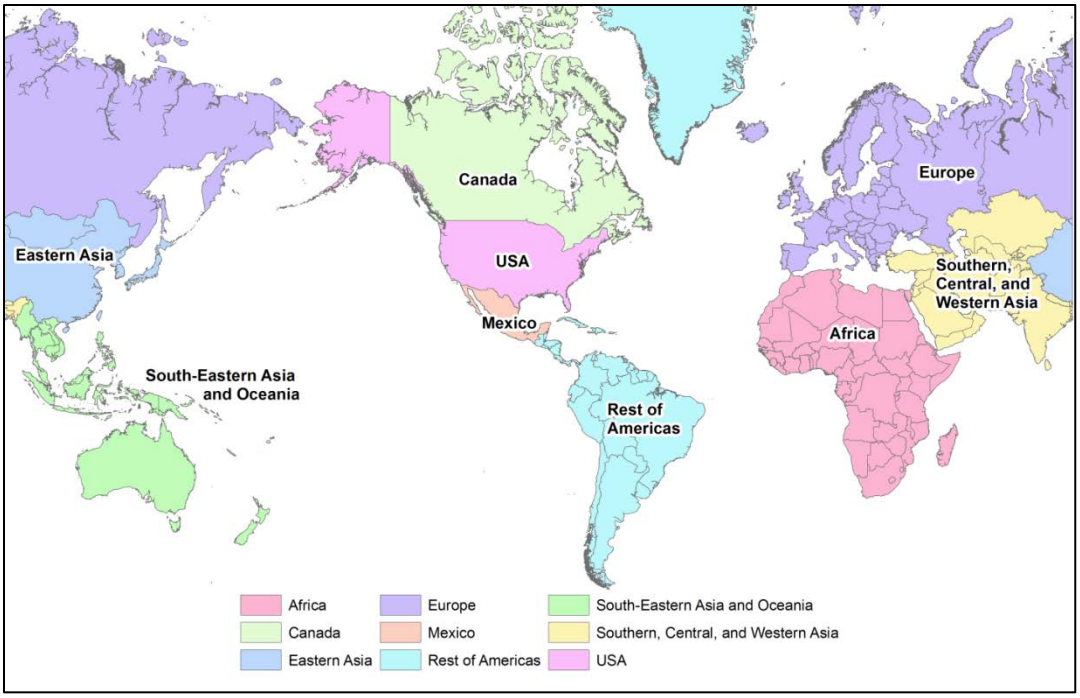
Overall, export and import trade is almost evenly distributed, with imports representing 51 percent of the total trade value. For Texas exports, the top 25 trade partners account for more than 85 percent of the value exported. For Texas imports, the top 25 trade partners account for more than 91 percent of the value imported (see Table 1).

Table 1. Texas's Top 25 Export and Import Trade Partners in 2014.

Exports				Imports			
Country	**Rank**	**Millions of Dollars**	**Percent of Exports**	**Country**	**Rank**	**Millions of Dollars**	**Percent of Imports**
Mexico	1	102,635	35.5%	Mexico	1	90,126	29.8%
Canada	2	31,118	10.8%	China	2	45,441	15.0%
Brazil	3	11,760	4.1%	Saudi Arabia	3	19,092	6.3%
China	4	10,986	3.8%	Canada	4	17,433	5.8%
Netherlands	5	8,911	3.1%	Venezuela	5	15,226	5.0%
South Korea	6	8,909	3.1%	South Korea	6	10,615	3.5%
Colombia	7	7,529	2.6%	Germany	7	8,732	2.9%
Singapore	8	5,776	2.0%	Kuwait	8	6,811	2.3%
Japan	9	5,538	1.9%	Japan	9	6,357	2.1%
Belgium	10	4,684	1.6%	Russia	10	6,242	2.1%
Venezuela	11	4,616	1.6%	Brazil	11	5,582	1.8%
United Kingdom	12	4,474	1.5%	Colombia	12	5,482	1.8%
Taiwan	13	4,111	1.4%	United Kingdom	13	5,184	1.7%
Chile	14	3,970	1.4%	India	14	4,037	1.3%
Ecuador	15	3,637	1.3%	Iraq	15	3,574	1.2%
Saudi Arabia	16	3,599	1.2%	Malaysia	16	3,494	1.2%
Argentina	17	3,388	1.2%	France	17	3,422	1.1%
France	18	3,263	1.1%	Costa Rica	18	3,147	1.0%
Panama	19	3,171	1.1%	Italy	19	2,925	1.0%
Germany	20	3,155	1.1%	Thailand	20	2,894	1.0%
Nigeria	21	2,764	1.0%	Taiwan	21	2,891	1.0%
Peru	22	2,745	0.9%	Vietnam	22	2,364	0.8%
United Arab Emirates	23	2,635	0.9%	Netherlands	23	2,278	0.8%
Australia	24	2,304	0.8%	Ecuador	24	1,642	0.5%
Turkey	25	2,222	0.8%	Belgium	25	1,616	0.5%
Rest of World		41,124	14.2%	Rest of World		25,465	8.4%
World		289,023	100.0%	World		302,073	100.0%

Source: U.S. Census Bureau 2015

The Federal Highway Administration (FHWA) Freight Analysis Framework (FAF) database includes freight movements for past and current years but also projects out to 2040. The database includes the estimated trade value of shipments to and from the United States and to and from foreign countries. The FAF database groups the foreign countries into eight international regions as shown in Figure 1.



Source: Federal Highway Administration 2012.

Figure 1. FHWA FAF World Regions.

Table 2 shows that the share of the value of goods traded with Texas for Mexico was 37 percent in 1997 but is expected to drop to slightly more than 26 percent in 2040. This loss of share is the result of the increase in share by eastern Asia (from 15.8 percent in 1997 to 25.0 percent in 2040); the rest of the Americas (10.2 percent to 12.9 percent); southern, central, and western Asia (4.9 percent to 5.9 percent); and Canada (8.8 percent to 9.4 percent). Specifically, Texas trade with eastern Asia is projected to increase dramatically, with levels approaching those of Mexico in 2040. Appendix A provides additional information on U.S. trade and trade partners.

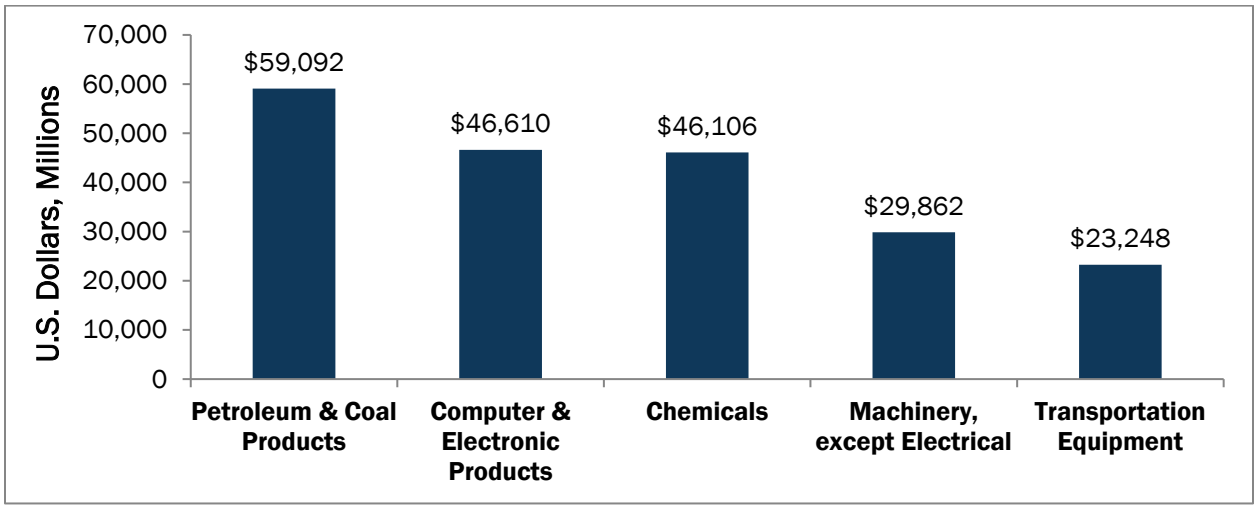
Table 2. FHWA FAF World Region Total Trade with Texas.

World Region	Percent Value		
	1997	2012	2040
Mexico	37.0%	34.0%	26.1%
Eastern Asia	15.8%	18.8%	25.0%
Europe	14.7%	14.0%	14.4%
Rest of the Americas	10.2%	11.0%	12.9%
Southern, central, and western Asia	4.9%	8.0%	5.9%
Canada	8.8%	7.5%	9.4%
Africa	4.0%	4.3%	3.2%
Southeast Asia and Oceania	4.6%	2.4%	3.2%

Source: Federal Highway Administration 2012.

TEXAS'S EXPORTS

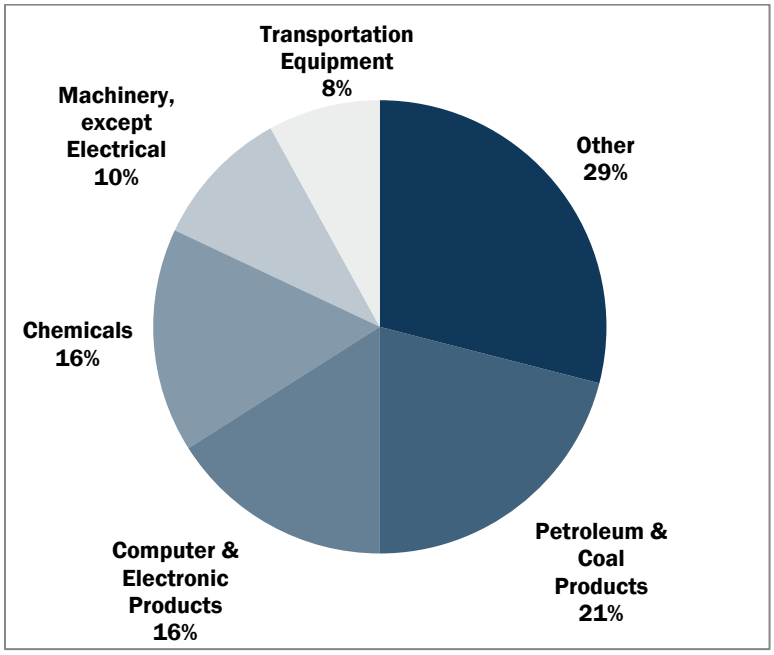
The U.S. Department of Commerce International Trade Administration (ITA) emphasizes the importance of exports in supporting employment. The $289.0 billion in exports from Texas (see Table 1) supported an estimated 1.1 million jobs in 2014 (U.S. Department of Commerce 2015). The largest category of exports in 2014 was petroleum and coal products at $59.1 billion (see Figure 2). This was followed by computer and electronic products at $46.6 billion, chemicals at $46.1 billion, machinery (except electrical) at $29.9 billion, and transportation equipment at $23.2 billion.



Source: U.S. Department of Commerce 2015.

Figure 2. Texas's Top Five Export Commodities in 2014.

Figure 3 shows the share of Texas's top five export commodities in 2014. These top five export commodities represented more than 70 percent of the total Texas export trade value in 2014.



Source: U.S. Department of Commerce 2015.

Figure 3. Shares of Texas's Top Five Export Commodities in 2014.

ITA also reports the exports for 387 U.S. metropolitan statistical areas (MSAs). Table 3 shows the total merchandise exports and the share of state exports reported for the MSAs in Texas. The table shows that the Houston–The Woodlands–Sugar Land MSA exported $119.0 billion in 2014, representing more than 41 percent of the total state exports of more than $288.0 billion in 2014.

Table 3. Texas's Exports by MSA in 2014.

Metropolitan Statistical Area	Total Merchandise Exports (Billions of Dollars)	Share of State Exports
Houston–The Woodlands–Sugar Land	119.0	41.3%
Dallas–Fort Worth–Arlington	28.7	10.0%
San Antonio–New Braunfels	25.8	9.0%
El Paso	20.1	7.0%
Austin–Round Rock	9.4	3.3%
Beaumont–Port Arthur	8.2	2.8%
Laredo	6.3	2.2%
Brownsville–Harlingen	5.4	1.9%
McAllen–Edinburg–Mission	5.3	1.8%
Corpus Christi	5.1	1.8%
Remainder of State	54.7	19.0%

Source: U.S. Department of Commerce 2015.

FACTORS IMPACTING GLOBAL TRADE

Trade Agreements

Currently, the United States has entered into 14 free trade agreements (FTAs) with 20 countries. Two additional FTAs are currently being negotiated. Table 4 lists the FTA partner countries.

Table 4. U.S. Free Trade Agreement Partner Countries.

Countries with Existing U.S. Free Trade Agreements	
• Australia • Bahrain • Chile • Columbia • CAFTA-DR: Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, and Nicaragua • Israel	• Jordan • Korea • Morocco • NAFTA: Canada and Mexico • Oman • Panama • Peru • Singapore
Countries Currently Negotiating U.S. Free Trade Agreements	
• TPP: Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, and Vietnam	• T-TIP: European Union

CAFTA-DR: Dominican Republic-Central America-United States Free Trade Agreement.
NAFTA: North American Free Trade Agreement.
TPP: Trans-Pacific Partnership.
T-TIP: Transatlantic Trade and Investment Partnership.

The trade agreements "reduce barriers to U.S. exports and protect U.S. interests and enhance the rule of law in the FTA partner country" (U.S. Department of Commerce n.d.-a). ITA notes that a reduction of trade barriers makes it easier and cheaper for U.S. companies to export their products and services to trading partner markets. U.S. exports to FTA partner countries account for almost half of all U.S. exports and nearly 70 percent of U.S. exports when considering existing and proposed FTA trade partners (U.S. Department of Commerce n.d.-b). Texas has benefitted from the FTAs, especially NAFTA with Canada and Mexico. ITA reports that more than 60 percent of Texas's exports in 2014 were to countries participating in current FTAs with the United States (U.S. Department of Commerce n.d.-c).

TPP deserves special mention in this research, given its potential to alter supply chains because some industries may restructure to take advantage of lower-production-cost countries. The 12 TPP countries combined represent 40 percent of the global gross domestic product and 25 percent of global exports (Cimino 2015). TPP developed from the Pacific 4 (P-4), which was created in 2006. The countries involved were Brunei, Chile, New Zealand, and Singapore. In 2008, the United States, Australia, Peru, and Vietnam joined the negotiations, which began TPP. In 2011, TPP partners committed to the broad outline of an agreement known as the Honolulu Declaration. In 2012, Canada and Mexico joined TPP negotiations, and in 2013, Japan joined as well (Mellor 2015). Negotiations to finalize the agreement are ongoing.

For example, the United States and Japan are currently engaged in talks that affect agriculture exports. If Japan agrees to reduce important tariffs, a major impediment to finalizing TPP will be removed. However, other impediments still require resolution, including intellectual property rights for pharmaceuticals and the new digital economy, investor-state dispute procedures, rules and enforcement of environment and labor protections, and issues involving state-owned enterprises.

The basic objectives of TPP are to:

- Expand opportunities for trade and investment in goods and services.
- Develop a comprehensive, new 21st century rulebook.
- Improve existing trade pacts among TPP.
- Reinforce economic and strategic ties among Asia-Pacific countries.

- Establish the foundation for broader Asia-Pacific and multilateral trade accords.
- Use TPP as a stepping stone for the eventual creation of a Free Trade Area of the Asia-Pacific (Cimino 2015).

TPP is also a response to the World Trade Organization's inability to solve global trade issues. Consequently, TPP has become a means for resolving NAFTA issues. For example, TPP addresses:

- Worker protection issues, such as workplace safety and collective bargaining.
- Specific environmental issues, such as overfishing and logging.
- Trade sanctions.
- The current business environment (e.g., e-commerce) (Bomba and Halbach 2015).

Finally, TPP is important to the U.S. economy because Asia and Oceania represent 26.9 percent of the world gross domestic product, and in the next five years Asia is expected to grow by $18.1 trillion. Furthermore, the population of Asia is projected to grow to almost 4.6 billion people by 2020. This population is projected to import $600 billion worth of goods in 2020. While U.S. exports to the Asia-Pacific market have steadily increased, the United States' share of the region's imports has declined by roughly 43 percent between 2000 and 2010. Currently, many Asian countries levy high tariffs on U.S. imports. For example, Korea has a rate of 12 percent, China has a rate of 9.6 percent, and India has a rate of 12 percent. A trade agreement with Asia could help the United States improve its share of the Asian market (Mellor 2015).

In summary, TPP has the potential to change supply chains, but it is unclear how Texas's NAFTA trade with Mexico will be impacted. Factors such as distance, labor costs, worker productivity, and currency valuation will ultimately determine the trade impacts. It is, however, relatively certain that the United States' trading relationship with Asia will strengthen. This growth will translate into increased port traffic. Port capacity and port access need to be evaluated in preparation for TPP (Bomba and Halbach 2015). A final agreement is anticipated in 2015.

National Export Initiative and Re-domestication of Manufacturing

In the 2010 State of the Union address, President Barack Obama announced the National Export Initiative (NEI), emphasizing it as a top priority to improve the conditions that directly affect the private sector's ability to export by:

- Working to remove trade barriers abroad.
- Helping firms and farmers overcome hurdles to entering new markets.
- Assisting with financing (U.S. Department of Commerce n.d.-d).

Ongoing efforts to support U.S. companies include:

- Continuing to build U.S. trade advocacy and export promotion efforts, including through initiatives such as the Doing Business in Africa Campaign.
- Promoting the availability of export financing.
- Educating U.S. companies about markets opened by FTAs, including the three that went into effect in 2012 (South Korea, Colombia, and Panama).
- Negotiating and concluding new trade agreements—such as the TPP agreement, the Trade in International Services agreement, and the T-TIP agreement—to address existing and newly emerging obstacles to U.S. exports in markets of opportunity.
- Enforcing U.S. trade rights under international agreements.
- Aggressively investigating unfair trade practices affecting U.S. exports or imports into the U.S. market (U.S. Department of Commerce n.d.-e).

The goal presented in 2010 was to double exports by the end of 2014. A synopsis of the NEI over the first four years indicates the doubling of exports may not happen on a national basis but that exports expanded by more than 50 percent between 2009 and 2012. Texas, however, is projected to meet the doubling-export goal (Coalition for America's Gateways and Trade Corridors 2014).

Much of this growth in U.S. manufacturing is a product of re-shoring. Companies have spent decades offshoring manufacturing and services to overseas countries, such as China, but a recent trend is the return of some of these activities to the United States. Offshoring has offered economic benefits to companies, but now the economics plus other factors have increased manufacturing in the United States. A January 2013 article in *The Economist* discusses three important reasons companies are reevaluating their global footprints (The Economist 2013a):

- The economic benefits of lower wages are much less now than they were 20 years ago. The article indicates that wages in China and India have experienced a 10 to 20 percent annual growth over the past decade, whereas manufacturing pay in America and Europe has remained the same.
- Many American firms realize they may have gone too far in sending work overseas. The article says that many firms discovered the disadvantages of distance, which affects the cost of shipping goods halfway across the world by sea and impedes innovation because of the separation of research and development from manufacturing.
- Firms appear to be moving away from the model of manufacturing everything in one low-cost place to supply the rest of the world. The trend now is to move production to be close to customers in big markets in an effort to be more responsive to changing local demands and customization requirements. Manufactured goods overseas may spend six weeks on a ship in transit, which does not allow for fast response times.

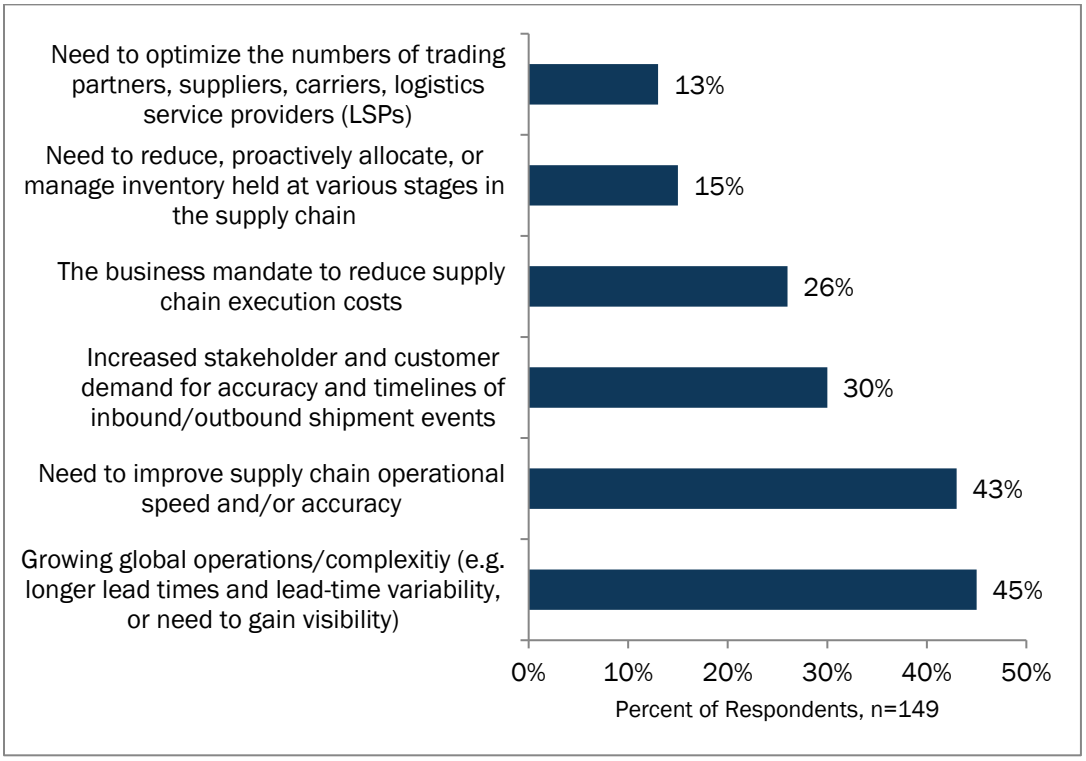
Another article in the same issue of *The Economist* indicates that the calculation to determine whether manufacturing is to be returned to the United States takes into account a wide variety of direct costs (e.g., labor, property, and transport) and indirect costs (e.g., supply chain risks) (The Economist 2013b). The article concludes that Mexico—with its distance advantage, which results in transit times of days instead of months, and labor costs only slightly higher than that of China—is increasingly attracting production destined for the United States (The Economist 2013b).

Trade Supply Chain Visibility

Supply chain visibility involves awareness and control of orders and shipments—including their progress before and during transit. Visibility is achieved by synchronizing technology and processes to improve the flow of shipments at all stages of the supply chain (Heaney 2013).

The Aberdeen Group conducted a survey of 149 countries with mostly global supply chains. Respondents identified the growing complexity of operations (45 percent) and the need to improve supply chain operational speed and/or accuracy (43 percent) as the two main concerns that drive the need for increased supply chain visibility (see Figure 4). Other concerns included

stakeholder demand for increased accuracy and timeliness of shipments, and the pursuit of cost reductions (Heaney 2013).



Source: Heaney 2013.

Figure 4. Concerns That Drive Supply Chain Visibility Requirements.

Deutsche Post DHL reported that supply chain visibility and security need to be improved in the future. Specifically, real-time information about supply chain delays (e.g., weather and port congestion) will be increasingly needed to allow logistics service providers to respond in a suitable manner (Deutsche Post DHL 2012).

Customs Regulations/Single Window System

The trend toward simpler customs regulations and electronic customs filing can potentially impact future trade. The benefits of electronic customs filing include faster document processing and a more efficient process. Electronic customs filing and associated data-mining tools may also reduce the need for the physical inspection of cargo at gateways (i.e., seaports, airports, and border crossings), which will reduce delays at the gateways and have associated improvements in the speed of the trade supply chain (Deutsche Post DHL 2012).

U.S. Customs and Border Protection (CBP) handles imports and exports in conjunction with 47 other agencies. Combined, these agencies require 200 forms, many of which are paper based or require repetitive information entry in various systems. CBP will transition to the Automated Commercial Environment (ACE) (the Single Window system) by the end of 2016. Through electronic reporting, traders will report exports and imports, and CBP will determine admissibility (U.S. CBP 2015). ACE will consolidate the process by requiring a single electronic entry of information and by eliminating paper (U.S. CBP 2015). The benefits of the Single Window system are expected to include reduced costs, real-time information, better communication among agencies, and easier compliance on the part of the trade community (U.S. CBP 2015). The trade community is anticipating that the Single Window system will enhance U.S. trade with its partners.

CHAPTER 3:
TEXAS' SOCIODEMOGRAPHIC TRENDS

With a 2013 population estimate of 26.4 million in Texas, demographic trends point to a younger population that is growing faster than that of the United States as a whole. Texas' higher-than-average birthrates and the strong pace of net migration are the two main drivers behind these trends. With a share estimate of 38.4 percent, Hispanics remain an increasing population cohort in Texas by birth and immigration from Mexico, where fertility rates are higher than in the United States (World Bank Group 2014).

Sociodemographic trends lie at the root of consumer demand and choices, and have a significant impact on the economic viability of any business model. This chapter provides information on a number of socioeconomic factors and the trends observed in Texas. The data and information, unless otherwise noted, are from *Changing Texas: Implications of Addressing or Ignoring the Texas Challenge* by Murdock et al. (2013).

TEXAS' POPULATION GROWTH

Historically, Texas' population growth rate has been higher than that of the United States and has been especially high during periods of economic expansion. During the oil boom of the 1970s, Texas grew 2.71 percent annually, compared to just 1.14 percent for the United States (World Bank Group 2014). In addition, immigrants kept the Texas population growing during the economic downturn of 2007 and its subsequent expansion. In 2013, Texas' net migration totaled 548,034, which included 179,930 international immigrants (U.S. Census Bureau 2013).

Comparison with Other States

Between 2000 and 2014, Texas had the largest numeric increase in population in the United States, with an increase of 4,293,741 between 2000 and 2010, and 1,811,397 between 2010 and 2014. California and Florida saw similarly high numeric population increases between 2010 and 2014 at 1,545,544 and 1,091,987, respectively. In terms of percentage of population increase, Texas' percentage of population increase ranked the second highest at 7.2 percent between 2010 and 2014. North Dakota experienced the highest percentage of population increase during this period with an increase of 9.9 percent. Table 5 provides information for the 10 U.S. states that had the largest population increases between 2010 and 2014.

Table 5. 10 U.S. States with the Largest Percentage of Population Increase from 2010 to 2014.

Place	April 1, 2000, Population	April 1, 2010, Population	July 1, 2014, Population	Change 2000–2010		Change 2010–2014	
				Numeric	Percent	Numeric	Percent
United States	281,421,906	308,745,538	318,857,056	27,323,632	9.7	10,111,518	3.3
North Dakota	642,200	672,591	739,482	30,391	4.7	66,891	9.9
Texas	20,851,820	25,145,561	26,956,958	4,293,741	20.6	1,811,397	7.2
Colorado	4,301,261	5,029,196	5,355,866	727,935	16.9	326,670	6.5
Utah	2,233,169	2,763,885	2,942,902	530,716	23.8	179,017	6.5
Florida	15,982,378	18,801,310	19,893,297	2,818,932	17.6	1,091,987	5.8
Arizona	5,130,632	6,392,017	6,731,484	1,261,385	24.6	339,467	5.3
Nevada	1,998,257	2,700,551	2,839,099	702,294	35.1	138,548	5.1
Washington	5,894,121	6,724,540	7,061,530	830,419	14.1	336,990	5.0
South Dakota	754,844	814,180	853,175	59,336	7.9	38,995	4.8
South Carolina	4,012,012	4,625,364	4,832,482	613,352	15.3	207,118	4.5

Comparison of Texas Cities

Table 6 shows that of the 20 cities with the largest numeric change in population between 2010 and 2014, five are in Texas: Houston, Austin, San Antonio, Dallas, and Fort Worth. Three of the five Texas cities (i.e., Houston, Austin, and San Antonio) ranked in the top five cities with the largest increase in population. During this time, Houston, Austin, and San Antonio's population increased by 6.7, 15.5, and 8.2 percent, respectively.

Table 6. 20 Cities with the Largest Numeric Population Change from 2010 to 2014.

Place	Population			Change 2013–2014		Change 2010–2014	
	2010	2013	2014	Numeric	Percent	Numeric	Percent
New York, NY	8,175,133	8,438,379	8,491,079	52,700	0.6	315,946	3.9
Houston, TX	2,099,451	2,203,806	2,239,558	35,752	1.6	140,107	6.7
Los Angeles, CA	3,792,621	3,897,940	3,928,864	30,924	0.8	136,243	3.6
Austin, TX	790,390	887,124	912,791	25,667	2.9	122,401	15.5
San Antonio, TX	1,327,407	1,411,766	1,436,697	24,931	1.8	109,290	8.2
Phoenix, AZ	1,445,632	1,512,442	1,537,058	24,616	1.6	91,426	6.3
Dallas, TX	1,197,816	1,260,725	1,281,047	20,322	1.6	83,231	6.9
Charlotte, NC	731,424	793,951	809,958	16,007	2.0	78,534	10.7
San Diego, CA	1,307,402	1,359,844	1,381,069	21,225	1.6	73,667	5.6
Fort Worth, TX	741,206	794,055	812,238	18,183	2.3	71,032	9.6
San Jose, CA	945,942	1,003,821	1,015,785	11,964	1.2	69,843	7.4
Denver, CO	600,158	648,401	663,862	15,461	2.4	63,704	10.6
Seattle, WA	608,660	653,404	668,342	14,938	2.3	59,682	9.8
Washington, DC	601,723	649,111	658,893	9,782	1.5	57,170	9.5
Columbus, Ohio	787,033	823,536	835,957	12,421	1.5	48,924	6.2
San Francisco, CA	805,235	841,138	852,469	11,331	1.3	47,234	5.9
Nashville–Davidson, TN	601,222	634,870	644,014	9,144	1.4	42,792	7.1
Oklahoma City, OK	579,999	611,030	620,602	9,572	1.6	40,603	7.0
New Orleans, LA	343,829	379,006	384,320	5,314	1.4	40,491	11.8

Predicted Growth

Figure 5 shows Texas' population growth between 1970 and 2010 and the predicted population growth between 2010 and 2050 using different migration assumptions:

- The population growth scenario indicated by the blue line assumes zero migration. This growth scenario is unlikely and is intended to function as a baseline.
- The population growth scenario indicated by the green line assumes half of the migration rate experienced between 2000 and 2010.
- The population growth scenario indicated by the red line assumes the same migration rate experienced between 2000 and 2010.

Figure 5 shows that Texas' population could reach between 32.1 million people (in the baseline case) and 55.2 million people (assuming the same levels of migration experienced between 2000 and 2010) by 2050. This translates into an increase of between 7 million and 30 million people between 2010 and 2050.

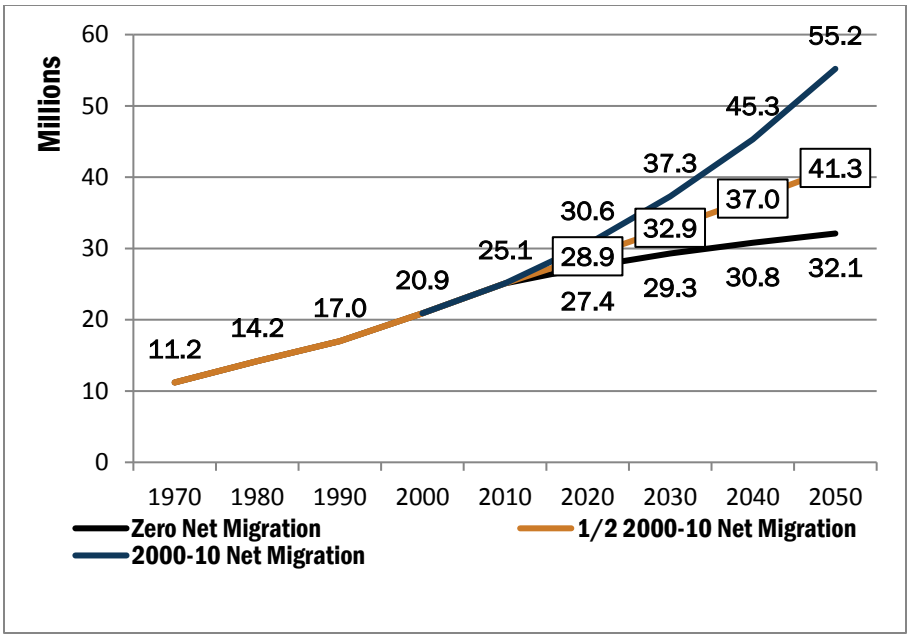


Figure 5. Population in Texas from 1970 to 2010 and Projected to 2050.

Given the projected population growth under the 2000–2010 net migration scenario, researchers estimated that the number of drivers and total annual miles of travel will increase dramatically between 2010 and 2050 (Table 7). Specifically, Texas would need an additional 371,753 road miles to accommodate the additional commuters if the number of drivers increases to 33,261,797 in 2050. This number only considers commuting traffic and does not account for an increase in freight movements to meet consumer demand.

Table 7. Projected Population, Licensed Drivers, Yearly Vehicle Miles of Travel, and Road Miles Needed from 2010 to 2050.

Year	Population	Drivers	Drivers per 1,000 Population	Yearly Vehicle Miles of Travel		Additional Road Miles Needed
				Per Driver	Total (in Billions)	
2010	25,145,561	15,157,650	602.8	13,475	204.2	-
2020	30,583,311	18,625,949	609.0	13,075	243.5	71,218
2030	37,282,785	22,708,486	609.1	12,688	288.1	155,050
2040	45,316,711	27,403,007	604.7	12,446	341.1	251,448
2050	55,205,530	33,261,797	602.5	12,276	408.3	371,753

TEXAS' POPULATION BY RACE AND ETHNICITY

Most of Texas' population increase, as a percentage of the total population change in Texas between 2000 and 2010, was in the Hispanic population cohort at 65.0 percent (see Table

8). The non-Hispanic (NH) Asian population cohort has increased by 71.1 percent between 2000 and 2010; however, this increase only represents 9.2 percent of the Texas population change between 2000 and 2010.

Table 8. Population, Population Change, and Proportion of the Total Population by Race/Ethnicity for Texas in 2000 and 2010.

Race/ Ethnicity*	Population			Population Change		Percent of Total Population	
	2000	2010	Numeric	Percent	Percent of Total Change	2000	2010
NH White	10,933,313	11,397,345	464,032	4.2	10.8	52.4	45.3
Hispanic (all races)	6,669,666	9,460,921	2,791,255	41.8	65.0	32.0	37.6
NH Black	2,364,255	2,886,825	522,570	22.1	12.2	11.3	11.5
NH Asian	554,445	948,426	393,981	71.1	9.2	2.7	3.8
NH other	330,141	452,044	121,903	36.9	2.8	1.6	1.8
Total	20,851,820	25,145,561	4,293,741	20.6	100.0	100.0	100.0

**Hispanic includes persons of all races. All other race/ethnicity categories shown here are non-Hispanic. "Non-Hispanic Other" includes persons identifying themselves as NH American Indian or Alaska Native, NH Native Hawaiian or Pacific Islander, NH some other race, or NH and a combination of two or more races.*

The race/ethnic makeup of Texas is changing. In 2000, the NH White population represented 52.4 percent of Texas' population. By 2010, the NH White population cohort represented 45.3 percent of Texas' population. The Hispanic population cohort has increased from 32.0 percent to 37.6 percent of Texas' total population.

Number of Children

These race/ethnic makeup population changes in Texas are also reflected in the number of children by race/ethnic cohort. Figure 6 shows increases in the number of Texas children for all races except NH White children between 2000 and 2010. The number of NH White children decreased by 184,000 between 2000 and 2010. In contrast, the number of Hispanic children increased by 931,000 between 2000 and 2010.

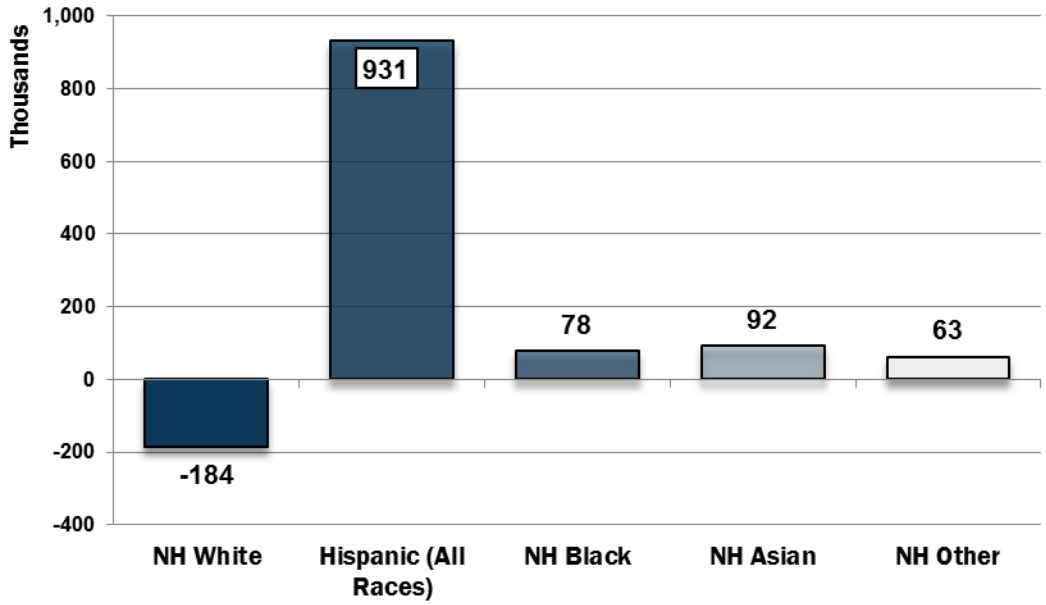


Figure 6. Numeric Change in Texas Children (Age Less than 18) Population (in Thousands) by Race/Ethnicity from 2000 to 2010.

Origin and Citizenship Status

Figure 7 shows that the Hispanic population in Texas is mostly native born (70.1 percent). Approximately 7.8 percent of the Hispanic population is naturalized citizens, and 22.2 percent is not U.S. citizens.

Of the native-born Hispanic population, nearly half (or approximately 3.1 million) are under the age of 18. Of the Hispanic population above the age of 18, 57.6 percent are native born, 11.6 percent are naturalized citizens, and 30.9 percent are not U.S. citizens.

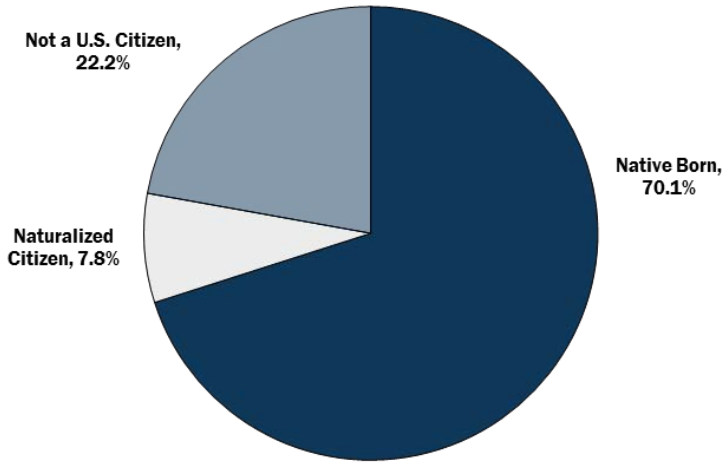


Figure 7. Hispanic Population in Texas by Origin and Citizenship Status.

Predicted Growth by Race/Ethnicity

Table 9 presents Texas' population by race/ethnicity in 2010 and projections of the population in Texas by race/ethnicity from 2020 to 2050 under alternative assumptions of age and race/ethnicity-specific rates of net migration:

- Assuming zero net migration, the Hispanic population will be approximately equal to the NH White population by 2020. By 2050, however, the Hispanic population will exceed the declining NH White population by approximately 6 million people.
- Assuming half of the net migration rate experienced between 2000 and 2010, the Hispanic population will be almost double the NH White population by 2050.
- Assuming the same net migration rate experienced between 2000 and 2010, the Hispanic population will be more than 2.5 times the NH White population by 2050.

NH Black and NH Asian populations are also expected to increase in each scenario. The largest increase (five times the 2010 population) will be in the Asian population cohort if a net migration equal to the 2000–2010 rate is assumed.

Table 9. Texas' Population by Race/Ethnicity in 2010 and Projections from 2020 to 2050.

Year	NH White	NH Black	Hispanic	NH Asian and Other	Total
Assuming Zero Net Migration					
2010	11,397,345	2,886,825	9,460,921	1,400,470	25,145,561
2020	11,576,595	3,122,637	11,137,672	1,536,693	27,373,597
2030	11,501,020	3,280,941	12,869,753	1,638,249	29,289,963
2040	11,182,576	3,355,500	14,570,851	1,714,232	30,823,159
2050	10,766,622	3,366,528	16,191,150	1,728,206	32,052,506
Assuming Net Migration Equal to Half of 2000–2010					
2010	11,397,345	2,886,825	9,460,921	1,400,470	25,145,561
2020	11,752,530	3,295,198	12,031,059	1,825,130	28,903,917
2030	11,850,180	3,658,997	15,082,058	2,309,763	32,900,998
2040	11,676,157	3,951,909	18,489,803	2,881,525	36,999,394
2050	11,376,576	4,182,155	22,268,390	3,483,178	41,310,299
Assuming Net Migration Equal to 2000–2010					
2010	11,397,345	2,886,825	9,460,921	1,400,470	25,145,561
2020	11,931,815	3,477,928	13,003,159	2,170,409	30,583,311
2030	12,211,664	4,080,453	17,702,132	3,288,536	37,282,785
2040	12,194,151	4,653,725	23,514,974	4,953,861	45,316,711
2050	12,024,913	5,195,861	30,701,208	7,283,548	55,205,530

Figure 8 further shows that assuming current demographic trends (i.e., net migration equal to the 2000–2010 rate), the Hispanic population cohort will account for 55.6 percent of the Texas population by 2050, while the NH White population cohort will account for 21.8 percent of the Texas population.

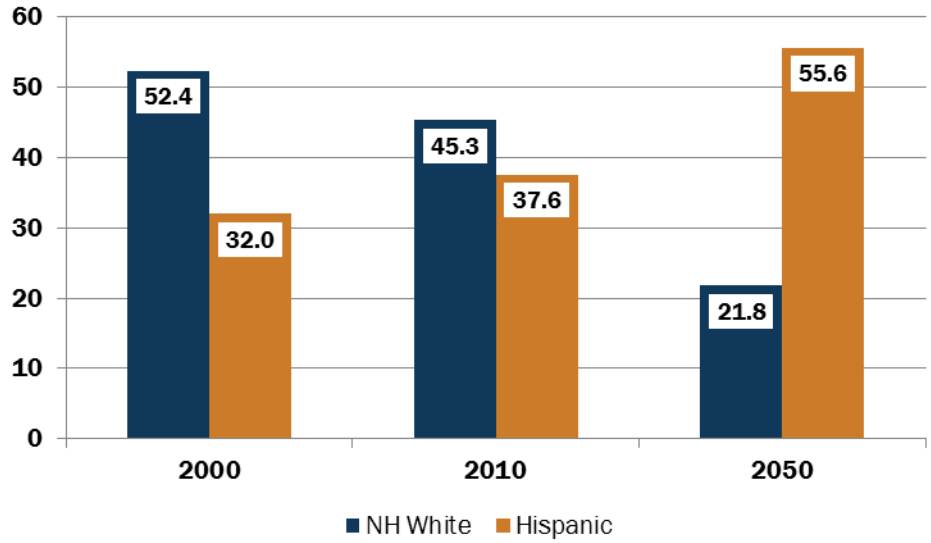


Figure 8. NH White and Hispanic Populations as a Percent of the Total Population in 2000 and 2010 and Projected in 2050.

In 2010, the NH White population cohort was larger than the Hispanic population cohort for the 35- to 39-year age group and all the older age groups (see Figure 9). Figure 10, however, shows that by 2050, the Hispanic population cohort will outnumber the non- Hispanic White population cohort in all age groups. The difference is more pronounced in the younger age groups (e.g., in the less-than-five-years age group, there will be four times more Hispanic children than non-White Hispanic children). But even for the 65+ age group, the Hispanic population will represent 42.5 percent, and the non-White Hispanic population will represent 35.7 percent of Texas' population in that age group.

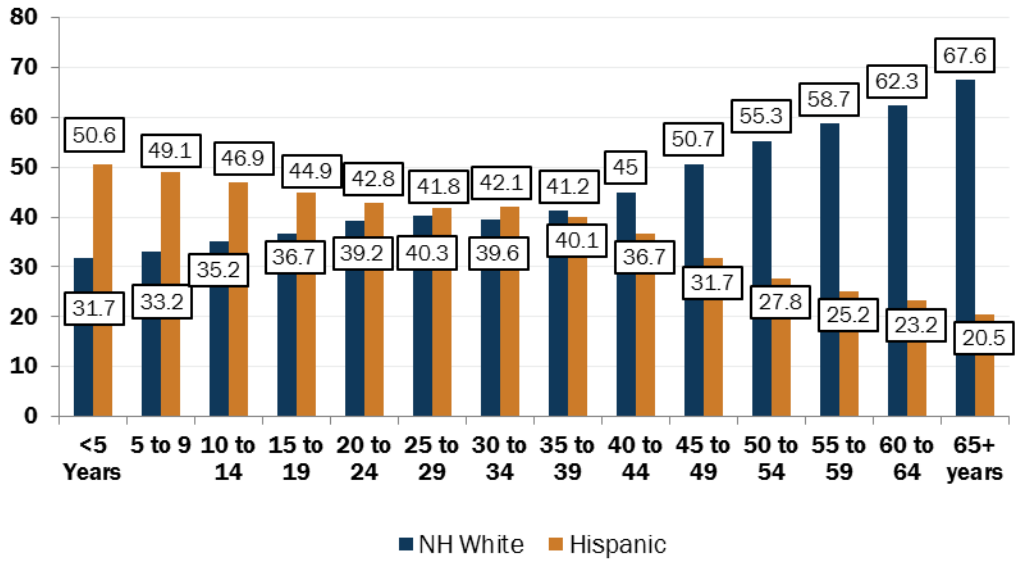


Figure 9. Percent of Texas Population by Age Group and Ethnicity in 2010.

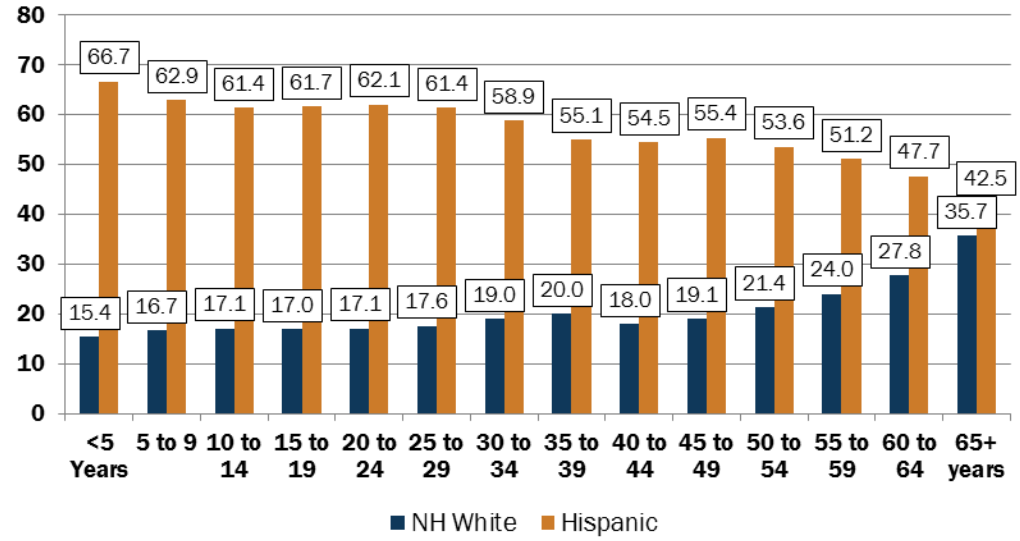


Figure 10. Percent of Texas Population by Age Group and Ethnicity in 2050.

URBAN/RURAL POPULATION DISTRIBUTION

Since 1900, Texas' population has been increasingly concentrated in urban areas, while the percentage of the population in rural areas has been declining. Figure 11 shows that in 1900, 17.1 percent of Texas' population resided in urban areas. By 2010, 84.7 percent of Texas' population resided in urban areas.

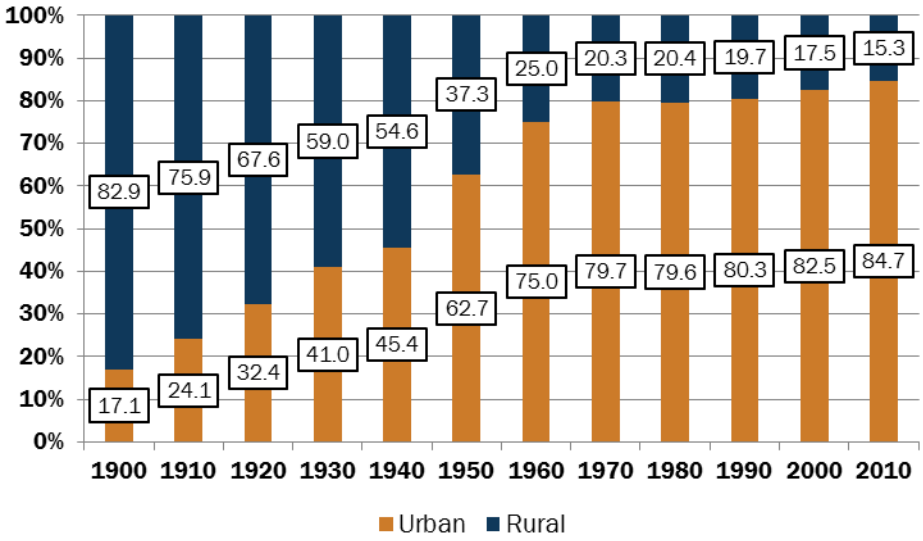


Figure 11. Change in Urban/Rural Population in Texas from 1900 to 2010.

Change in Population between 2000 and 2010

Figure 12 shows the population change in Texas counties between April 1, 2000, and April 1, 2010:

- The counties colored red and orange saw a reduction in population.
- The counties colored blue saw the largest increase in population.

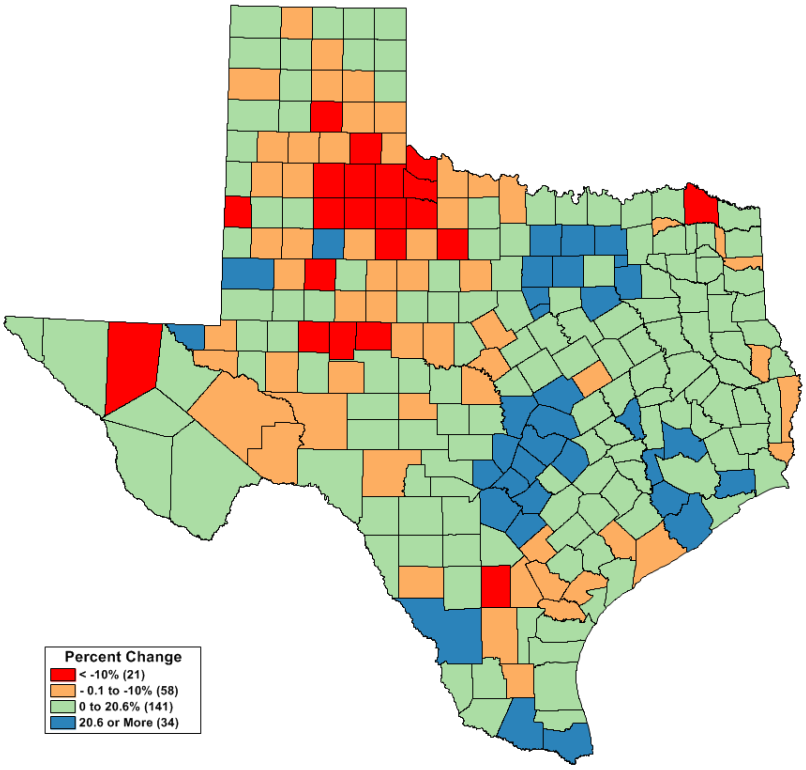


Figure 12. Population Change in Texas Counties from April 1, 2000, to April 1, 2010.

Texas counties that experienced the largest growth contained large metropolitan areas (i.e., Austin, Dallas, Houston, and San Antonio) or were in South Texas—most notably counties with international border crossings (i.e., Brownsville, Hidalgo, and Laredo). Most of the population decline occurred in rural counties in West Texas.

Change in Population between 2010 and 2014

Figure 13 shows the population change in Texas counties between April 1, 2010, and July 1, 2014:

- The counties colored red and orange saw a reduction in population.
- The counties colored blue saw the largest increase in population.

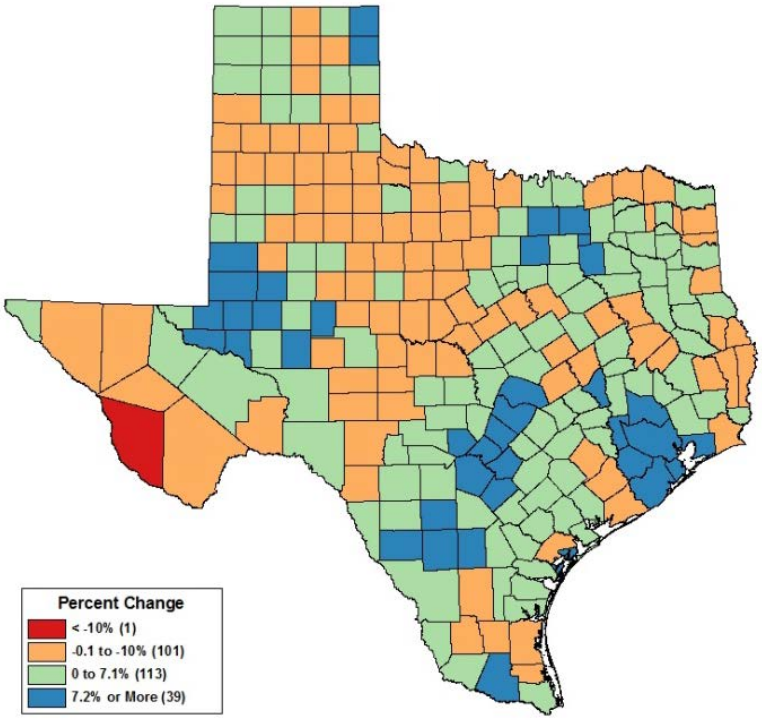


Figure 13. Population Change in Texas Counties from April 1, 2010, to July 1, 2014.

From 2010 to 2014, more counties saw a decline in population than in 2000 to 2010. Also, metropolitan areas and South Texas continued to see growth. Counties in West Texas and the Eagle Ford Shale have experienced high population growth (i.e., more than 7.2 percent) due to increased oil drilling in the area.

SUBURBAN LIFESTYLES

Data from the Environmental Systems Research Institute (Esri) Tapestry Segmentation Lifestyle provide information about U.S. residential households—what they buy and how they spend their free time. U.S. residential areas are divided into 67 segments based on demographic variables such as age, income, home value, occupation, household type, education, and other consumer behavior characteristics. The following subsections provide a demographic and market snapshot for each of the six major cities in Texas and compare their demographic and market data with the entire United States (Esri Corporation 2014).

Austin

Austin had a 2013 population of 885,400, according to the 2013 U.S. Census estimate. The 2014 Esri Tapestry reports a population of 2,020,620 living within a one-hour driving time.

According to Esri Tapestry's "up and coming families" lifestyle classification:

- They live in the suburbs.
- Most are professionals employed in management occupations.
- Thirty-seven percent are college educated, above the average for the United States of 28 percent for the same lifestyle category.
- They have a household annual income of $80,516, compared to $70,173 in the United States.
- The unemployment rate is 7 percent, below the 11 percent in the United States for the same lifestyle category.
- They live in single-family units and are married couples with children.
- The household size is 2.6, the same as the U.S. average.
- The median age is 33 years, compared to 37 in the United States.
- Most drive more than 20,000 miles annually. Eleven percent bought or leased a new vehicle last year.
- They have an estimated retail expenditure of $2,302 per month, compared to $2,072 in the United States for the same lifestyle category.
- They spend $2,156 on travel per year, 13 percent more than the U.S. average for the same lifestyle category.

Dallas

Dallas had a 2013 population of 1,257,676, according to the 2013 U.S. Census estimate. The 2014 Esri Tapestry reports a population of 6,378,581 living within a one-hour driving time.

According to Esri Tapestry's "boomburbs" lifestyle classification:

- They live mainly in the urban outskirts.
- Most are professionals employed in management occupations.
- Thirty percent are college educated—higher than the United States average of 28 percent for the same lifestyle category.

- They have a household annual income of $81,554, compared to $70,173 in the United States.
- The unemployment rate is 9 percent, compared to 11 percent in the United States for the same lifestyle category.
- They live in single-family units and are married couples with children.
- The household size is 2.8, compared to 2.6 in the United States.
- The median age is 33.4 years, compared to 37 in the United States.
- Most own or lease a sports utility vehicle. Ten percent bought or leased a new vehicle last year.
- They have an estimated retail expenditure of $2,325 per month, compared to $2,072 in the United States for the same lifestyle category.
- They spend $2,179 on travel per year, 15 percent more than the U.S. average for the same lifestyle category.
- Most shop predominantly online.

El Paso

El Paso had a 2013 population of 674,433, according to the 2013 U.S. Census estimate. The 2014 Esri Tapestry reports a population of 935,871 living within a one-hour driving time.

According to Esri Tapestry, people in this region are “southwestern families”:

- Most are Hispanic.
- Most are employed in skilled occupations and services.
- Twenty percent are college educated—below the U.S. average of 28 percent for the same lifestyle category.
- They have a household annual income of $49,643, compared to $70,173 in the United States.
- The unemployment rate is 11 percent, same as the 11 percent in the United States for the same lifestyle category.
- They live in single-family and multi-family units, and their household extends beyond the immediate members.
- The household size is 3.0, more than the 2.6 U.S. average.
- The median age is 31 years, compared to 37 in the United States.

- Nine percent bought or leased a new vehicle last year.
- They have an estimated retail expenditure of $1,442 per month, compared to $2,072 in the United States for the same lifestyle category.
- They spend $1,260 on travel per year, 33 percent less than the U.S. average for the same lifestyle category.

Fort Worth

Fort Worth had a 2013 population of 792,727, according to the 2013 U.S. Census estimate. The 2014 Esri Tapestry reports a population of 6,238,461 living within a one-hour driving time.

According to Esri Tapestry, people in this region are “boomburbs”:

- Most are professionals employed in management occupations.
- Thirty-one percent are college educated, above the average for the United States of 28 percent for the same lifestyle category.
- They have a household annual income of $81,170, compared to $70,173 in the United States.
- The unemployment rate is 9 percent, below the 11 percent in the United States for the same lifestyle category.
- They live in single-family units and are married couples with children.
- The household size is 2.8, more than the 2.6 U.S. average.
- The median age is 33.4 years, compared to 37 in the United States.
- Ten percent bought or leased a new vehicle last year.
- They have an estimated retail expenditure of $2,314 per month, compared to $2,072 in the United States for the same lifestyle category.
- They spend $2,168 on travel per year, 13 percent more than the U.S. average for the same lifestyle category.
- Most shop online.

Houston

Houston had a 2013 population of 2,195,914, according to the 2013 U.S. Census estimate. The 2014 Esri Tapestry reports a population of 5,910,674 living within a one-hour driving time.

According to Esri Tapestry's "milk and cookies" lifestyle classification:

- Most are professionals employed in management or skilled occupations.
- Twenty-eight percent are college educated.
- They have a household annual income of $75,255, compared to $70,173 in the United States.
- The unemployment rate is 10 percent, compared to 11 percent in the United States for the same lifestyle category.
- They live in single-family units and are predominantly married couples with children.
- The household size is 2.9, compared to 2.6 in the United States.
- The median age is 33.3 years, compared to 37 in the United States.
- They own or lease minivans. Ten percent bought or leased a new vehicle last year.
- They have an estimated retail expenditure of $2,149 per month, compared to $2,072 in the United States for the same lifestyle category.
- They spend $2,006 on travel per year, 5 percent more than the U.S. average for the same lifestyle category.
- They eat at fast-food restaurants often.
- They buy children's toys and games.

San Antonio

San Antonio had a 2013 population of 1,409,019, according to the 2013 U.S. Census estimate. The 2014 Esri Tapestry reports a population of 2,209,465 living within a one-hour driving time.

According to Esri Tapestry's "southwestern families" lifestyle classification:

- They live mainly in the urban outskirts.
- Most are employed in skilled occupations.
- Twenty-four percent are college educated, below the average for the United States of 28 percent for the same lifestyle category.

- They have a household annual income of $61,910, compared to $70,173 in the United States.
- The unemployment rate is 8 percent, compared to 11 percent in the United States for the same lifestyle category.
- They live in single-family units with a household-type family mix.
- The household size is 2.8, compared to 2.6 in the United States.
- The median age is 34.1 years, compared to 37 in the United States.
- Most have a car loan. Ten percent bought or leased a new vehicle last year.
- They have an estimated retail expenditure of $1,791 per month, compared to $2,072 in the United States for the same lifestyle category.
- They spend $1,615 on travel per year, 14 percent less than the U.S. average for the same lifestyle category.
- They buy children's products.

MEDIAN AGE

Figure 14 shows that the median age in the United States and in Texas has increased between 1900 and 2010. In 2010, the median age in the United States was 37.2 years, while in Texas it was slightly lower at 33.6 years.

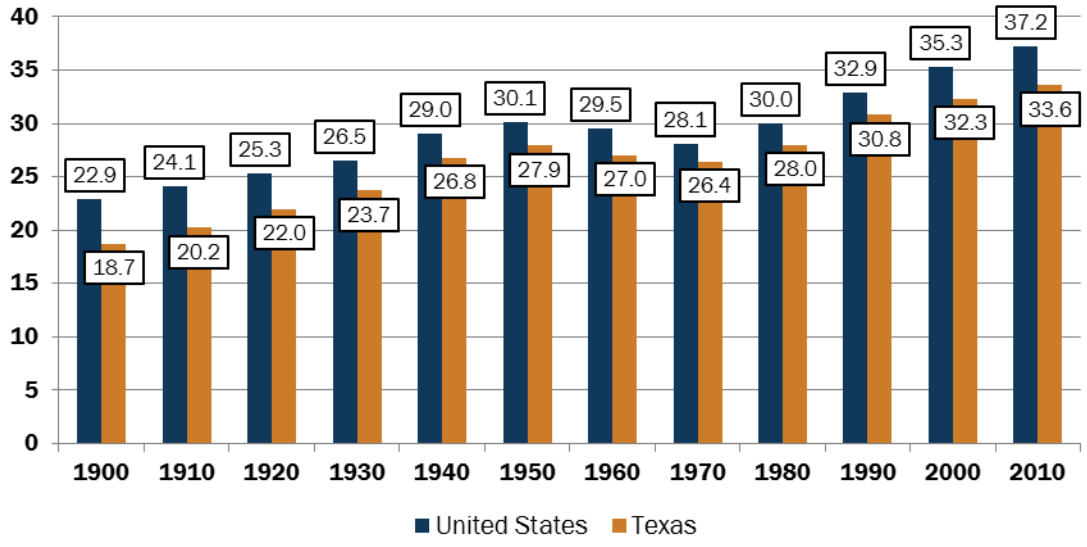


Figure 14. Median Age in the United States and Texas (1900–2010).

65 and Older

Figure 15 and Figure 16 show the percentage of the Texas population aged 65 or older by Texas county in 2010 and predicted for 2050. As the Texas population continues to age, it is predicted that by 2050, more than half of the Texas counties will have 20 percent or more of the county population represented by the 65 or older age cohort.

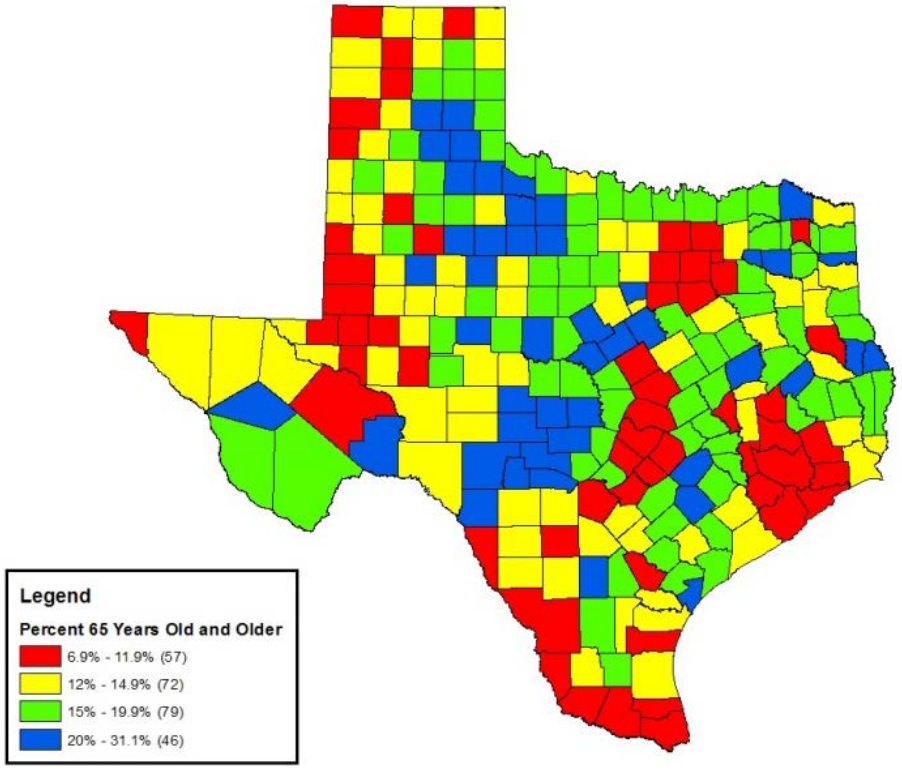


Figure 15. Population Age 65 and Older by Texas County in 2010.

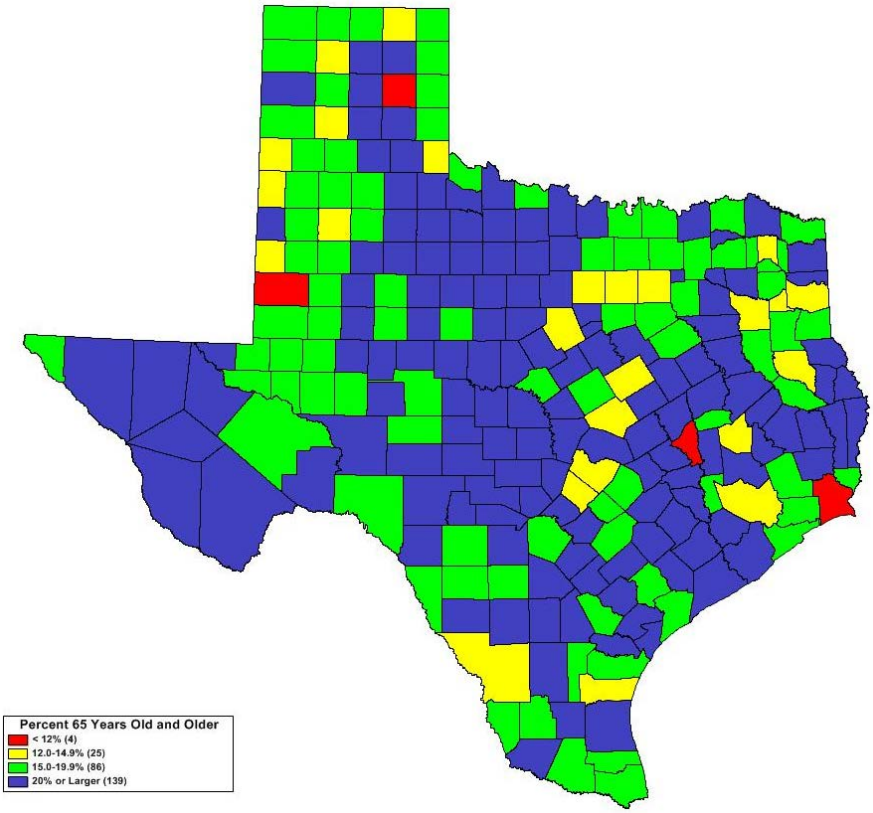


Figure 16. Predicted Population Age 65 and Older by Texas County in 2050.

Licensed Drivers

An aging population has resulted in an associated increase in the percentage of licensed drivers in the older age cohorts. Figure 17 shows that the percentage of licensed drivers in the above 45 years old age cohorts has increased substantially, with the largest percentage increase in the licensed drivers in the 80 years and older age cohort.

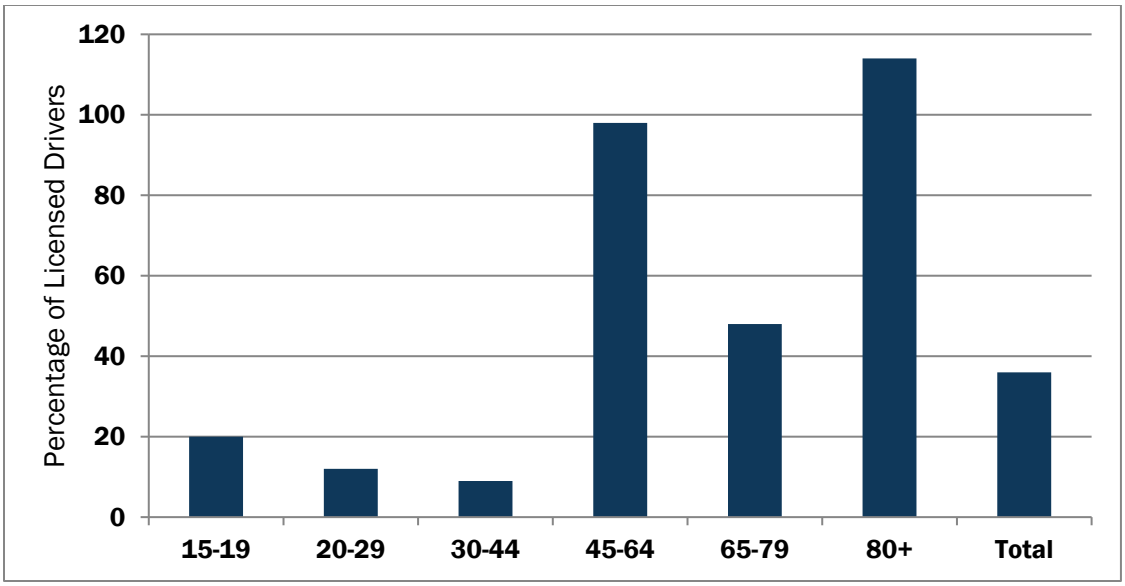


Figure 17. Percentage Change in Texas Licensed Drivers by Age Group (1990–2010).

EDUCATION

Figure 18 points to educational disparities among racial/ethnic groups in the United States and Texas. Eight percent of the NH White population 25 years or older had less than a high school education in 2010. In contrast, 13.7 percent of NH Black, 14.3 percent of NH Asian, and 40.4 percent of the Hispanic population 25 years or older had less than a high school education in 2010.

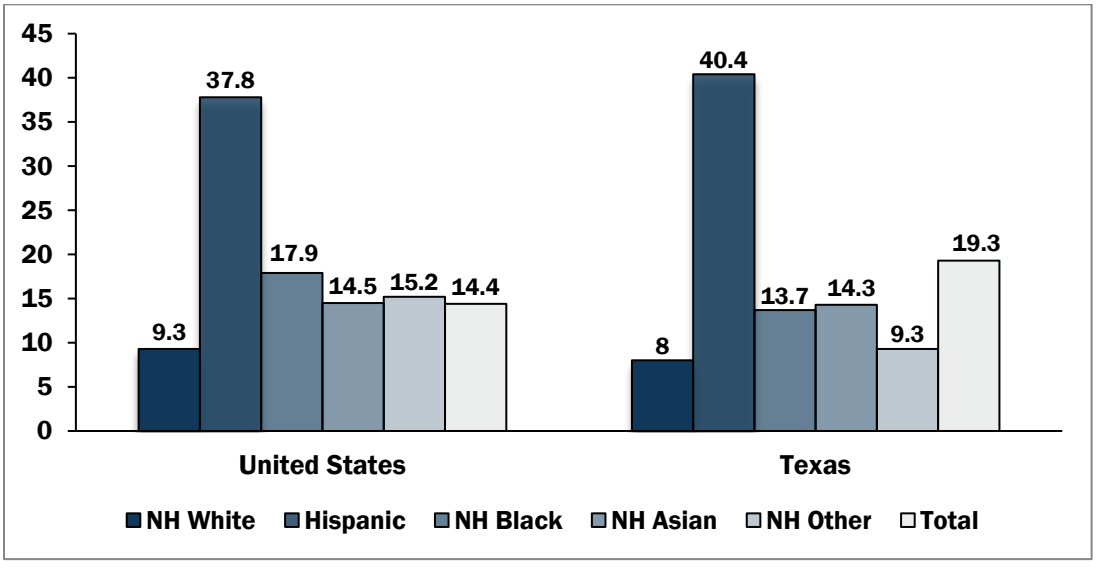


Figure 18. Percent of the U.S. and Texas Population Age 25 and Older with Less than High School Diploma/GED by Race/Ethnicity (2010).

Enrollment and education expenditures have increased since 2000. Enrollment at all education levels has increased by 21 percent since 2000. Expenditures have increased 24.8 percent for primary and secondary school, translating into a 3 percent increase per student since 2000. Expenditures have also increased for higher education in Texas by 10 percent, translating into a 28.1 percent decrease per student since 2000.

INCOME

Figure 19 shows the median household, family, and per-capita income for each of four main race/ethnic cohorts in Texas in 2010. In 2010, the median household income was $61,049 for NH Whites, $60,110 for NH Asians, $37,019 for Hispanics, and $36,466 for NH Blacks. Hispanics and NH Blacks had median household incomes 60 percent and 65 percent of NH Whites, respectively. The median family income and per-capita income of Hispanic households was also lower than that of NH households.

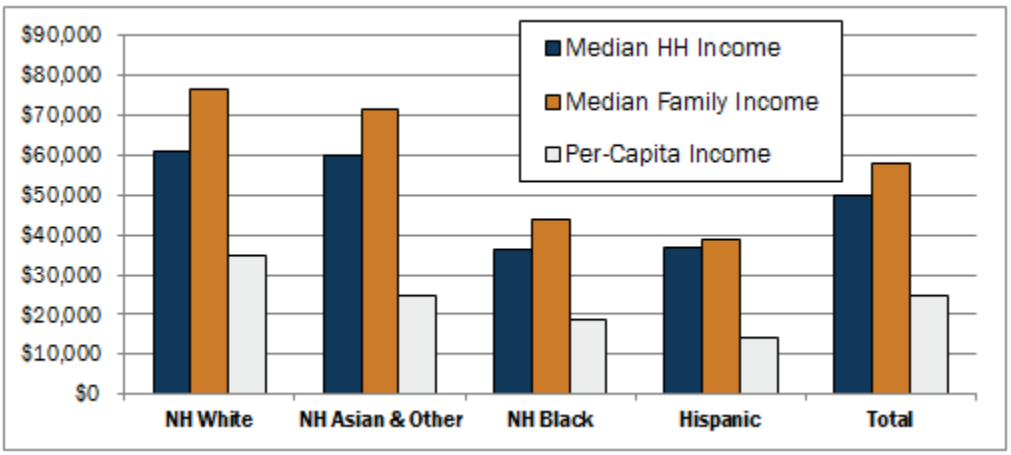


Figure 19. Texas' Median Household Income, Family Income, and Per-Capita Income by Race/Ethnicity in 2010.

CONCLUSION

The sociodemographic factors and projections presented in this chapter will impact the demand for transportation and freight services in Texas. For example, demographic changes impact car ownership and the number of licensed drivers. This is important because individuals who own cars typically travel longer distances and consequently have access to more job opportunities.

An important predictor of car ownership is income. The disparity in income between NH Whites and Hispanics and other minorities means fewer minorities own cars and hold driver's licenses. Low-income NH Blacks in urban areas, for example, used public transportation more frequently than any other group in 2000 and 2010. Similarly, low income, job type, and a lack of access to public transportation have resulted in a higher carpooling rate by Hispanics relative to other racial/ethnic groups.

Also, older age groups have seen an increase in the number of drivers. One of the consequences of this trend is an increase in non-peak-period driving because many of these drivers are no longer working. This could potentially impact freight deliveries in urban areas.

These differences point to changes in the demand for transportation services as the composition of the Texas population changes and the trends remain unchanged.

CHAPTER 4:
ENVIRONMENTAL TRENDS

A review of the environmental and climate change literature reveals a number of physical changes to the environment that will impact transportation infrastructure and disrupt supply chain operations in the future if no action is taken. This chapter outlines the impact extreme weather and climate change could have on transportation infrastructure and the potential regulatory, industry, and consumer responses that could emerge in response to extreme weather events.

ENVIRONMENTAL IMPACTS ON TRANSPORTATION INFRASTRUCTURE

Environmental changes (e.g., altered long-term climatic averages and the frequency and severity of extreme weather events) caused by climate change could have a substantial impact on transportation infrastructure, trade corridors, and transportation costs. According to the National Centers for Environmental Information, Texas experienced three extreme weather events in 2014 that resulted in more than $3 billion in damage (National Centers for Environmental Information n.d.). Furthermore, the Southern Plains Transportation Center (2014) noted that extreme summer temperatures, flash floods, and the large number of freeze-thaw cycles, coupled with poor soils in most Region 6 states,[1] create challenges to transportation infrastructure health and to public safety. The result has been losses worth nearly $9 billion annually to manage transportation systems in Oklahoma and Texas.

Extreme weather conditions can create significant challenges for transportation infrastructure. The body of current knowledge is in agreement that extreme weather events are likely to be much more of an issue to many state transportation agencies in the future (National Research Council 2013). *Transportation Research Board Special Report 290: Potential Impacts of Climate Change on U.S. Transportation* (Transportation Research Board 2008) identified five specific concerns that will directly affect transportation systems over the next 50 to 100 years:

- Sea-level rise (virtually certain—99 percent probability).
- Rise in Arctic temperatures (virtually certain—99 percent probability).

[1] Region 6 states are Arkansas, Louisiana, New Mexico, Oklahoma, Texas, and 66 Tribal Nations.

- More very hot days with concomitant heat waves and fewer cold days (very likely—90 percent probability).
- Changes in precipitation levels and frequency (very likely—90 percent probability).
- Increase in the intensity of strong hurricanes (likely—67 percent probability).

Increases in temperature, changes in precipitation patterns, and rising sea levels will all impact freight transportation in the future. The following subsections provide additional information about the potential impacts of climate change on transportation infrastructure.

Temperature

Climate change affects global temperatures and seasonal weather patterns. An increase in maximum temperatures and a shift in temperature ranges will have a direct impact on freight transportation infrastructure.

Increase in Maximum Temperatures

Higher maximum temperatures and extended heat waves create premature deterioration of infrastructure and equipment. Roads, rail, and bridges will be damaged from buckling, rutting, and thermal expansion (Meyer et al. 2014). Higher temperatures soften asphalt, overheat vehicles, and stress bridge joints. New roadway and railway materials will be needed to mitigate the deterioration of existing construction materials. Equipment will need new cooling systems to eliminate overheating. Most of the freight transportation infrastructure and equipment in warmer climates will need to be upgraded or replaced (Meyer et al. 2014). Load restrictions might also be enacted to reduce deterioration of roads and railways.

Shift in Temperature Ranges

Shifts in temperature ranges affect seasonal weather and snow thaw. Decreases in frozen precipitation will improve safety and reduce winter travel hazards in northern areas. This will increase freight movement and lower costs due to winter road maintenance. Less salt and chemicals will be needed for winter weather precautions, limiting their corrosive and polluting effects. Additionally, roads built on permafrost will see damage due to the settling and spreading of embankments. Compromised embankments also increase the likelihood of landslides, slope instability, and shoreline erosion. These conditions damage roads, bridges, and railways (Meyer et al. 2014).

Precipitation

Changes in precipitation patterns (e.g., prolonged drought and excessive rainfall) may burden freight transportation infrastructure in the future. The impacts will vary across the nation, with some states facing drought and others experiencing excessive rainfall.

Drought

Drought is a visible effect of climate change. Sixty percent of the United States experienced some degree of drought in 2014, and 20 percent was under extreme conditions. Droughts dilute surface salt and cause concrete steel reinforcement to corrode. This form of reinforcement is used throughout the transportation system. Road embankments, bridges, and rail will consequently have weakened structural integrity. Droughts also dry out construction materials, leading to cracking and crumbling (Meyer et al. 2014).

Excessive Rainfall

Excessive rainfall increases soil moisture levels, weakening structural foundations. Regions with excessive rainfall may see increased transportation safety risks and accidents. Bridges and all suspended passageways will be in jeopardy. Excessive rainfall also leads to flooding and mudslides. These extreme conditions damage tunnels, culverts, and other underground infrastructure. Flash floods wash away infrastructure and equipment. Mountainsides and other high-elevation areas will have mudslides that could destroy freight transportation infrastructure and disrupt system lines (Meyer et al. 2014).

Sea Level

Sea levels are projected to rise over the next 40 years. Higher sea levels will destroy or displace ports, coastal highways, and railways.

Flooding

Permanent and temporary flooding will be common in coastal and low-lying areas. This encroachment of saltwater leads to corrosion and degradation of tunnels, bridges, and other infrastructure. The salt will corrode bridge joints, embankments, and railways.

Floodwaters may permanently close tunnels and bridges. Roadways will need to be rerouted or abandoned to avoid new flood zones.

Loss of Barriers to Storms

Higher sea levels also remove the protection of barrier islands, increasing the damage from waves and extreme storms. Hurricanes may become more prevalent due to climate change. Because of the loss of barrier islands, these intense storms and hurricanes could hit settlement areas with more force and destroy more infrastructure (Meyer et al. 2014).

REGULATORY RESPONSES TO ENVIRONMENTAL CHANGE

The transportation sector accounts for an estimated 14 percent of global greenhouse gas (GHG) emissions. This share is anticipated to increase as the demand for freight increases (Deutsche Post DHL 2012). The U.S. Environmental Protection Agency (EPA) stated that transportation accounts for 27 percent of GHG emissions in the United States, with over half of the emissions from passenger cars and light-duty trucks. The remainder is emitted by other transportation modes, such as freight trucks, commercial aircraft, ships, trains, and pipelines (U.S. EPA n.d.). Logistics will therefore be of strategic importance in the move toward a low-carbon economy (Deutsche Post DHL 2012).

Governments have started to adopt environmental regulations to reduce criteria pollutants and have entered into climate protection negotiations to mitigate the effects of climate change. These regulations (e.g., emissions reduction requirements for trucks and rail) currently affect freight and will continue to affect freight in future years, given increased regulations to reduce criteria pollutants and GHG emissions. The European Commission, for example, has set a target of a 60 percent reduction in GHG emissions from the transportation sector (Deutsche Post DHL 2012). A key policy in the European Commission's plan to reduce carbon from the transportation sector is to have 50 percent of truck freight that travels over distances of 300 kilometers or more move by rail or waterways by 2050 (Deutsche Post DHL 2012). Diverting freight to low-carbon-intensity modes (in terms of the grams of carbon dioxide per ton-kilometer) is regarded as one of the most effective policies to reduce the carbon footprint of the logistics sector (Deutsche Post DHL 2012). Other regulatory responses are discussed in the following subsections.

International Regulations

A National Cooperative Highway Research Program study titled *Driving Forces Influencing Future Freight Flows* surveyed freight stakeholders to "identify, categorize, and rank

the driving forces and critical uncertainties that will influence the future freight transportation flows within the United States over the next 30 years" (Caplice and Phadnis 2010). In terms of the environmental regulations, the study reported the following:

- About 57 percent believed that a global environment council will be created and international climate regulations will be generally present in the future.
- Another 28 percent believed that international regulations will be at least widely present. Participants believed freight transportation will have to adapt to keep pace with changing regulations and regulators.
- About 50 percent believed state, federal, and international regulations on social responsibility, environmental emissions, resource usage, and trade practices will be omnipresent before 2055. Participants believed the end result could be a web of conflicting rules and penalties (Caplice and Phadnis 2010).

Fuel Economy Standards

On June 19, 2015, the U.S. EPA and the U.S. Department of Transportation proposed new GHG and fuel efficiency standards for heavy trucks. These standards will build upon the first-ever GHG and fuel economy standards for new freight trucks and buses that were finalized in 2011. The agencies also announced new performance standards for heavy- and medium-duty trucks and tractor-trailers—a proposal that will reduce emissions by 1 billion metric tons and reduce oil use by 1.8 billion barrels.

Additionally, the U.S. EPA's Tier 4 locomotive emission standards took effect on January 1, 2015. These standards apply to newly manufactured and remanufactured locomotives and engines. The Obama Administration announced in July 2015 that it was moving toward addressing emissions from commercial airplanes as well.

Eom et al. (2012) report that higher fuel economy standards can result in advances in the design of ships, trucks, and rail that could increase the fuel efficiency of these freight modes. The increased use of new lightweight materials can also improve fuel economy. Several studies have forecasted improvements of 20 to 40 percent in the fuel efficiency of freight vehicles, vessels, and aircraft by 2020 or 2030 (Deutsche Post DHL 2012). However, the long life cycles of maritime, aviation, and rail equipment slow the diffusion of new technologies in these sectors and may also slow improvements in fuel efficiency.

Carbon Taxes

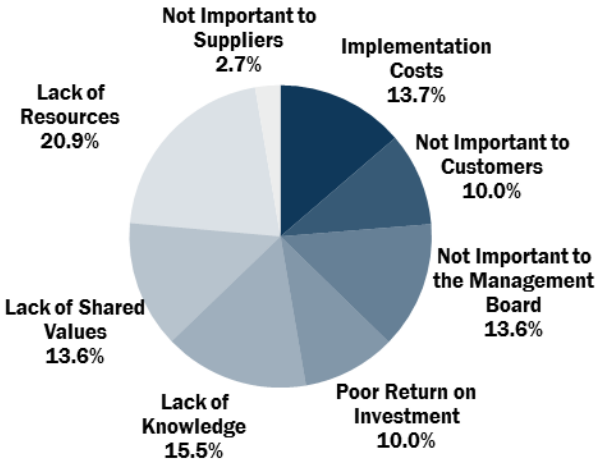
In an effort to address climate change, governments have started to tax not only fuel but also carbon emissions. These carbon taxes are typically paid by consumers of the product to internalize the resources used in the manufacture/production and the transportation of the product. Ehrhart (2013) argues that carbon pricing will lead to more stringent regulatory measures. Companies will only accept the price tag on carbon emissions if governments ensure a level playing field (Ehrhart 2013).

In the United States, federal and state taxes on gasoline and diesel are used to pay for highway infrastructure, but these taxes have not been increased since 1993. The recently introduced American Opportunity Carbon Fee Act aims to reduce GHG emissions by 40 percent by 2025. The act levies a $45 tax on each metric ton of emissions emitted. The fee will apply to all companies that extract or import fossil fuels and to large emitters of GHGs (Sheppard 2015).

INDUSTRY RESPONSES TO ENVIRONMENTAL CHANGE

As freight demand increases, emissions and fuel consumption are projected to increase as well. Policy makers and industry are expected to use sustainable practices to reduce the impact of freight on the environment. According to Mattila and Antikainen (2011), policy makers and freight industry leaders acknowledge the importance of reducing emissions, but they disagree on the best option to do so.

Eyefortransport (eft) surveyed senior supply-chain executives representing manufacturers and retailers in preparation for the 2015 Chief Supply Chain Officer Forum (Reynolds 2015). Responses were received from 173 executives. More than 40 percent of respondents indicated that sustainability is extremely important to their business. On the other hand, almost 20 percent of respondents indicated that sustainability was slightly important/not at all important to their business. Figure 20 identifies the most important impediments in achieving greater supply chain sustainability, according to survey respondents (Reynolds 2015).



Source: Reynolds 2015

Figure 20. Biggest Obstacle to Achieving Greater Supply Chain Sustainability.

Research has shown that implementing sustainability practices for freight transportation will be more difficult than for passenger transportation (University of Leeds Institute for Transport Studies 2010). The following subsections discuss emerging industry responses to extreme weather events.

Renewable Energies/Alternative Fuels and Technologies

Global road freight activity is expected to triple by 2050 (Mattila and Antikainen 2011). Akerman and Hojer (2006) report that the current business-as-usual model will not result in sustainable freight transportation; to reduce transportation emissions, the freight industry will have to move to biofuels and more efficient vehicles. It is generally predicted that the use of renewable energy will become more widespread in the future (Deutsche Post DHL 2012).

The trend toward the use of renewable fuels has already started. DHL in Bonn, Germany, uses specially designed electric trucks to make shipments. The delivery truck holds 1.5 workdays of battery life and emits zero GHGs. Bonn will operate 141 electric DHL vehicles by 2016, decreasing carbon emissions by more than 500 tons per year (Deutsche Post DHL n.d.).

The move toward the use of renewable fuels is hampered by the fact that many of these renewable or alternative fuels are currently not economically competitive with conventional fuels used in the freight sector. Alternative fuels could become more prevalent and cost effective with the help of technology. For example, improvement in the cost, weight, and battery life of electric vehicles would decrease emissions associated with certain freight modes.

Fuel Cell Trucks

Fuel cell trucks are an emerging technology. These trucks have zero emissions and create electricity by mixing oxygen with hydrogen stored on board the truck. The benefits of fuel cell trucks include increased energy efficiency, quiet operation, and reduced GHGs.

The following are some implementations of fuel cell trucks:

- The Memphis International Airport, in its effort to become a zero emissions airport, has acquired fuel-cell-powered ground support vehicles and equipment.
- The Port of Los Angeles/Long Beach uses five fuel cell drayage trucks and hopes to expand its fleet of fuel cell drayage trucks in the future (Satyapal 2015).
- Hydrogenics has developed an all-inclusive hydrogen fuel cell system for medium- and heavy-duty truck and bus markets. The company claims that its fuel cell system will meet operators' expectations in terms of reliability, durability, fuel efficiency, affordability, quiet operation, and easy maintenance (Pringle 2015).

Improved Vehicle Utilization

Vehicle utilization is an indicator that aims to measure how effective the freight sector is in transporting goods with its vehicles. In other words, the same amount of goods would be transported with fewer vehicles if each vehicle's carrying capacity were fully used. This would contribute to reducing total freight vehicle traffic, thereby leading to reduced congestion, emissions, and other environmental impacts imposed by freight transportation (European Environment Agency 2010).

Manufacturers can reduce costs through better vehicle utilization with a reduction in package size and weight and use of fewer packing materials. This allows for more truck space to be used and fewer truck trips. A number of changes in operations have emerged in an effort to enhance vehicle utilization:

- First, shippers are increasingly considering shipment consolidation. They are scrutinizing their own processes to find opportunities to consolidate their shipments and are considering the possible leverage that could be gained from using a third-party logistics provider to match shipments along shared routes.
- Second, shippers are focusing on optimizing capacity utilization by building their own multiproduct containers, pallets, or cartons (Russell et al. 2014).

The following are examples of measures implemented to improve vehicle utilization:

> *"A Delphi survey of 100 logistics specialists in the UK indicated that, on a business-as-usual basis, it would be possible to cut the empty running of trucks by 19% and raise average payload weight by 12%, between 2006 and 2020" (Deutsche Post DHL 2012).*

- A variety of Kraft Food products "cubed out" before they "weighed out." In other words, the truck's volume limit was reached before its weight limit was reached. The result was that Kraft's refrigerated outbound shipments only utilized 82 percent of the truck's weight capacity on average. Kraft used specialized software to maximize truck usage without damaging products. As a result, Kraft removed 6.2 million truck miles and reduced truckload costs by 4 percent.
- The world's largest retailer, Walmart, increased the number of pallets shipped in a truck from 26 to 30 simply by introducing side-loading pallets.
- Stonyfield Farms, a dairy product manufacturer, worked with its clients to help decrease the use of inexpensive or waste material to protect cargo in transit, allowing the company to maximize the available space per trailer (Mathers 2015).

Information and Communication Technologies

It is anticipated that information and communication technologies (ICT) will play a major role in developing more sustainable strategies for freight transportation in the future. ICT will improve the efficiency of the transportation network with more efficient scheduling, tracking, and routing, along with the consolidation of, for example, warehouse capacity. Specifically, an ICT option that could become more available in the future is the development of electronic freight exchanges. Freight exchanges would encourage better utilization of unused capacity across different transportation modes (i.e., decrease number of empty or half full vehicles), improving the efficiency of the freight system with an associated decrease in emissions and lessened impact on the environment.

For example, Schneider National, a long-haul trucking company, linked the Internet to its back-end transportation management system to assist customers with finding the cheapest and fastest methods for delivering their products across the country. Schneider uses its own fleet to

aggregate shipments and also contracts out shipments to other delivery services, such as FedEx and UPS (Duvall 2000).

RightFreight.com, a business-to-business website, assists shippers with identifying freight forwarders, freight forwarders with finding the best prices on air carriers, and air carriers with filling up empty cargo spaces through a bidding system. Freightquote.com allows businesses to choose the delivery location, pickup times, and rates for domestic trucking deliveries by providing an online marketplace. It is similar to FreightDesk.com, which serves the international freight forwarder market (Head2Head 2000).

Carbon Labeling

Carbon labeling is a growing trend, with products being labeled with their carbon footprint. Carbon emission reduction during production, packaging, and shipping is the goal. Companies that issue carbon labels already exist, such as Carbon Trust, a British-based organization. Businesses such as Coors, Pepsi, Halifax, and Tesco have adopted carbon footprint labels for many of their products.

Freight and logistics companies are researching better ways to quantify carbon emissions while also increasing transparency. A few methodologies can be used to calculate GHGs produced by freight logistics systems, such as the European standard DIN EN 16258. These methodologies can provide recommendations to operators on how best to reduce carbon emissions (Ehrhart 2013).

Some freight and logistics companies are also sharing carbon data with neutral third parties for analysis, comparison, and recommendations. Collaboration among freight competitors is a growing trend to help reduce carbon emissions industry-wide. It is predicted that carbon labeling will become standard practice.

Reverse Logistics

Reverse logistics is the process of transporting returned, damaged, or unwanted products from their current location to one where they will be reused, repaired, or disposed of. Reverse logistics operations are currently conducted separately from standard freight operations (Hawks 2006). Recent research in the United Kingdom has shown that the integration of reverse shipments and outbound freight operations—new products shipped with returned, damaged, or unwanted products—would decrease total freight vehicle movements. This would decrease total

GHG emissions and make freight transportation more sustainable. A number of companies have implemented reverse logistics, including the following:

- Unyson manages the movement of returned, damaged, or unwanted products for clients. Unyson enters each item in its tracking system, thereby allowing for full visibility of return shipments in transit to a distribution center or return center for disposal or reconstitution (Malone 2005).
- Roadway Reverse Logistics handles Hyundai's reusable parts for the remanufacture of transmissions from Hyundai dealers. As Roadway acquires the part, it enters the part in its system and credits the dealer (Malone 2005).
- Estee Lauder profited from a $1.3 million investment in reverse logistics. Before implementing reverse logistics, the company lost more than $60 million worth of products returned by retailers each year (Genco n.d.).

Supply Chain Redundancy

The literature documents concerns about global warming impacting trade corridors and supply chains. Although the melting of the Arctic ice may open up shorter and more efficient trade corridors, the threat of extreme weather events is expected to result in more frequent disruptions of trade routes and supply chains (Deutsche Post DHL 2012). Catastrophic events (e.g., the closure of all East Coast ports from New York to Virginia as a result of Hurricane Sandy) will disrupt lean trade supply chains and result in supply chain failures in the movement of all types of goods. This could call for more contingency planning and disaster response, and ultimately a move away from efficiency maximization to more redundancy in supply chains (Deutsche Post DHL 2012).

Redundancy in a supply chain means having backup systems, alternative routes, or excess capacity and allows for products or services to be moved along the system in the event of disturbances along the supply chain. A redundancy plan means that an organization will be less vulnerable to unforeseeable events or failures along the supply chain because the organization's critical infrastructure incorporates various methods, strategies, or services to fulfill its supply chain needs. Supply chain redundancy has already proven itself invaluable when unexpected events have taken place (Keenan 2006).

Innovative Urban Freight Transportation Practices

New urban freight transportation practices are being considered to increase sustainability. Efficient urban freight has been a long-standing problem for the industry, but a solution is possible involving a coordinated package of incentives for more sustainable and innovative freight vehicles. New lightweight freight trams could transport freight in and around urban centers with no GHG emissions (University of Leeds Institute for Transport Studies 2010). Another approach is an underground delivery network. These urban projects have not been pursued because of the high cost and low demand. Projected trends in increased sustainable freight demand and new innovative rail systems could lead to an expansion of urban freight transportation systems in the future.

CONSUMER RESPONSES TO ENVIRONMENTAL CHANGE

The Massachusetts Institute of Technology conducted a National Cooperative Highway Research Program study looking into the future of freight. The freight stakeholders that participated in the study were divided about the extent to which consumers would demand sustainable products by 2055. The majority of freight stakeholders believed that consumers may have at least general information about the sustainability practices and carbon footprints of products. Sustainable and low-carbon-footprint products could, however, become a marketing trend in 2055, which will require freight transportation to adapt (Caplice and Phadnis 2010).

If societal demands in 2055 require sustainably produced and low-carbon-footprint projects, then shipping and logistics companies will need to make adjustments to ensure sustainable freight transportation. This will put pressure on the freight transportation industry to make changes and to have sustainable practices because consumers will make selections considering product and shipping/transportation sustainability. In addition, if carbon labeling becomes standardized, carriers with the smallest carbon footprint will become industry favorites.

This shift in consumer demand will encourage cleaner and more sustainable freight transportation. Transparency will, however, be required to instill confidence among logistics customers and end consumers when making climate-friendly choices (Deutsche Post DHL 2012).

CHAPTER 5:
TECHNOLOGY TRENDS

In many ways, technology can be both a driver and enabler of transformation in logistics and a disrupter of logistics. For example, electronic commerce (or e-commerce) was initially an enabler for consumers to buy and sell goods easily via the Internet. With its widespread use globally, e-commerce has changed the face of the supply chain and logistics. For small and large retailers, e-commerce offers an easy way to access the global marketplace.

In the supply chain and logistics, technology offers many new applications, such as tagged goods that already "know" their entire life cycle and can autonomously steer their way, and refrigerators that generate supply orders for groceries when their contents fall below a specified level. These capabilities are embedded in traditional infrastructure, and the separation between online and offline is vanishing (Deutsche Post DHL 2014). The World Wide Web itself has become part of the supply chain infrastructure.

This chapter discusses the following technologies as it relates to the supply chain:

- Current technologies (e.g., RFID and GPS) that shippers and freight carriers use to manage their operations.
- Technologies accessible to consumers that are reshaping demand for goods and services (e.g., e-commerce).
- Emerging technologies that have the potential to transform the supply chain (e.g., 3D printing, truck platoons, and automated vehicles).

CURRENT TECHNOLOGIES AND THEIR FUTURE TRENDS

Radio Frequency Identification

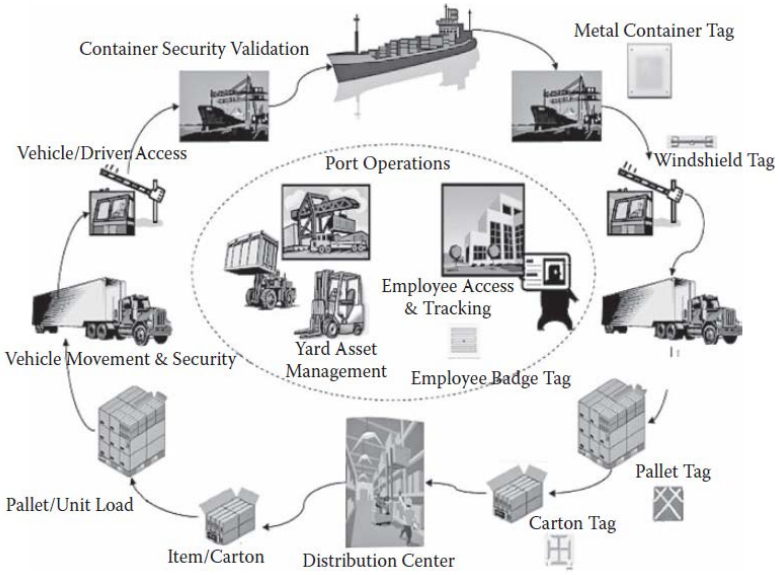
RFID is a contactless or wireless method of identifying objects. The RFID tag typically consists of a silicon chip that can hold a small amount of data (e.g., a unique identification number). An external reader communicates with the RFID tag by sending and receiving radio-frequency waves. Typically, a backend system is connected to the readers to store, retrieve, and manage information tied to individual tags.

Benefits

The benefits of RFID in logistics, transportation, and warehousing are:

- **Labor and time savings.** RFID reduces the labor and time required to identify objects and perform other manual processes, such as counting, stacking, and documentation. This also improves the accuracy of inventory processes.
- **Benefits from increased visibility.** By using RFID, retailers and logistics companies have exact knowledge of the amount of inventory at each step in the supply chain in real time, which creates multiple levels of visibility. The added value of RFID is mainly detection of presence (Gaukler and Seifert 2007).

The emergence of RFID technology has resulted in increased efficiency in the production management process, material flow management, logistics and transportation, and retail and distribution industries, including the electronic information industry. Figure 21 shows the relationships within the supply chain that can be affected by the implementation of RFID technologies.



Source: Clampitt 2007

Figure 21. SAVI Technologies Integrated Supply Chain with RFID.

Adoption of RFID

Several large suppliers and retailers have adopted RFID technology:

- Walmart requested its top 100 suppliers adhere RFID tags to the vessels and boxes (especially of high-profit products) by January 2007.

- The U.S. Department of Defense requires its equipment suppliers to use RFID tags.
- Metro is the fifth-largest retailer in the world and Germany's largest retailer. Its mandate was very similar to the Walmart mandate.
- Tesco and Marks and Spencer, the largest retailers in the United Kingdom, initiated similar RFID mandates, further influencing suppliers to use RFID technologies.

The use of RFID has increased tremendously because of what economists call the network effect, which states that the more entities that use a physical network or shared service, the more valuable it becomes (Roberti 2003). Over the years, the cost of RFID has decreased substantially.

In addition, the market penetration of RFID does not show any signs of slowing down. According to IDTechEx (n.d.), the global market for RFID transponders, readers, software, and services will increase 17 percent from 2013 to 2014. Furthermore, the RFID market is expected to increase from $9 billion to $30 billion by 2024. Government, retail, and transportation and logistics have been identified as the most important markets and are expected to account for 60 percent of accumulated revenue over the next five years (IDTechEx n.d.).

> *"Seniors living at home have their weekly medication delivered to an automated box which dispenses the daily ration and controls patients' compliance. The patients' daily routines are monitored by an array of sensors, measuring a person's fluid intake, for example, or, using an RFID sensor in the shoe to measure their mobility" (Deutsche Post DHL 2012).*

Evolving Technology

RFID tags are also evolving. Enhanced RFID tags (with sensor and memory functionalities) go beyond tracking and tracing. For example, enhanced sensors can provide information on the condition of goods as they move through the supply chain or can measure or monitor mobility. Also, an active area of research is a hybrid system with an RFID tag nested within a GPS receiver. If tags and receivers were able to communicate with one another, more accurate real-time data could be collected during the transportation of products (Jones and Chung 2008).

A possible application of this nested technology is in the railroad industry. Currently, two passive RFID tags are attached to the sides of all railcars in the United States. In addition, most railroads use GPS receivers to track locomotives. If nesting became possible, active tags could be used to capture the cargo information in all railcars, which could then be transmitted to the GPS receiver and subsequently to the inventory databases.

Global Positioning System

GPS has been a game changer over the last few decades. GPS has moved from the military into civilian engineering surveying and then into recreational pursuits, navigation, and smartphones. GPS user equipment has undergone a dramatic transformation from very heavy, expensive, analog-based electronics to tiny digital devices that can be embedded within mobile phones. This means the technology can be attached to more and more things.

Benefits

GPS technology has helped improve the reliability of the supply chain by increasing the visibility of goods along the supply chain. Using real-time information on the location of goods, companies have enhanced the visibility of the cargo and can track cargo to estimate arrival times, optimize routes, track fuel costs, and manage resources.

While it has become increasingly common to see the technology being used to locate the fleet and cargo, there are fewer instances of its use on the factory or warehouse floor. This is primarily because GPS is still more expensive than RFID and bar codes and because the technology lacks the precision for locating items within an enclosed space.

Evolving Technology

By the end of the decade, GPS will lose its monopoly and will be but one component of a navigation system that includes the European Union's planned Galileo system and possibly the Russian Federation's GLONASS. GPS, Galileo, and GLONASS will, however, be compatible and interoperable so that user equipment can be developed to use some or all of the broadcast signals. For example, iPhone already has GLONASS chips. The modernization of GPS and the deployment of Galileo will have a profound impact on future navigation system receiver designs (Rizos 2003). Such receivers will permit much higher positioning accuracy, reliability, and coverage.

TECHNOLOGIES ACCESSIBLE TO CONSUMERS

Electronic Commerce

Electronic commerce, commonly known as e-commerce, is the trading of products or services using computer networks, mostly the Internet. Current e-commerce draws on technologies such as mobile communication, the World Wide Web, electronic funds transfer, Internet marketing, online transaction processing, inventory management systems, and automated data collection systems. Today's e-commerce typically uses the World Wide Web for at least one part of the transaction's life cycle. E-commerce impacts all three components of the supply chain:

- Physical flow of goods between suppliers, retailers, and consumers.
- Information that is available to all parties at all times.
- Financial flow through faster payment and settlements.

Benefits

E-commerce has shortened the supply chain transaction time, expanded the boundaries of operation, increased the amount of volume that the supply chain network can manage, and reduced the cost of logistics, procurement, and inventory holding (Management Study Guide n.d.).

Adoption of E-commerce

Companies such as Amazon and eBay have been in the forefront of online retail. For everyday consumers, e-commerce is synonymous with online shopping with these companies. Traditional and big-box retailers such as Walmart and Target are trying to catch up by providing consumers with the ability to order online and pick up at the store. Amazon recently announced that it will start delivering fresh groceries in a few cities, and even Google announced a same-day shipping service.

Industry analysts agree that e-commerce has potential for growth, even in developed markets such as the United States and Europe. Penetration of e-commerce in the retail industry is still less than 10 percent globally. Worldwide sales are expected to exceed $1 trillion in 2016 (Boesler 2013). With increasing penetration of high-speed Internet and smartphones, e-commerce will continue to grow globally in the future.

Mobile Devices and Smartphones

An increasing number of consumers are ordering goods, making payments, and tracking orders using smartphones. This trend is expected to increase because smartphones still constitute a relatively small percentage of the overall mobile phone market in Asia, Latin America, and Africa where online retail is still in its infancy. Even in the United States and Europe, smartphones constitute only 75 percent of the overall mobile phone market.

Mobile computing devices, whether in the form of smartphones or tablet computers, could also have a more far-reaching impact on logistics. The appeal of these devices lies largely in their flexibility. With a tablet or smartphone in hand, managers/supervisors no longer need to return to their desks to obtain essential operating data. They can pull up the information wherever they are—whether in the warehouse or on the road. Mobile phones provide a constant connection to logistics operations. Suppliers and logistics service providers can simply use their smartphones to provide status updates or respond to issues. Higher levels of connectivity, communication, and engagement among supply chain partners result in increased and accelerated information sharing and improved supply chain performance (Parsons 2013).

Also, more and more truck drivers have access to smartphones equipped with GPS, location tracking, and routing software to find optimal routes to get to their destinations on time. Employees entering the logistics workforce today have been raised with smartphones, and they will be the drivers of its widespread adoption in managing logistics in the future.

On-Demand Economy and Convenience Logistics

The on-demand economy is defined as the economic activity created by technology companies that fulfill consumer demand via the immediate provision of goods and services (Jaconi 2014). The new on-demand models have created real-time fulfillment of goods and services, which consumers have embraced at an unprecedented rate. Studies have shown that buying goods online does not always have a price advantage over buying offline at a retail store. Therefore, price is not the only factor when consumers choose to buy online. The convenience of choosing goods, comparing prices, and receiving the items at home are key reasons consumers buy online.

The on-demand economy's growth is a product of consumers' growing desire for greater convenience, speed, and simplicity facilitated by hyper-connectivity and fast Internet access.

High-speed Internet, smartphones, cloud computing, big data, and hyper-connectivity are the digital backbone of the on-demand economy.

Getting Close to the Customer

In 2012, Curtis and Ehrenfeld reported that global trade depends on reliable, inexpensive freight transportation—often along complex long-distance supply chains—and explored the economic logic of comparative advantage[2] for global supply chains. He argued that global supply chains will be overcome by increased transportation costs and delays within the freight system. He stated that supply chains will shorten in length, and production will be located closer to consumption points in the future. This trend has started to materialize; getting close to the customer has become the new mantra for retail companies and shippers in recent years.

In large urban areas where transportation and congestion are increasing, being close to customers makes sense for shippers and retailers that have adopted same-day deliveries. Same-day deliveries increase the requirement for last-mile, small-package delivery services (Goodwill 2013).

Amazon is an example of a company that has embraced getting closer to the customer. Amazon is investing in Amazon Lockers in certain retail establishments so consumers can have the option to pick up their merchandise at locations that are convenient for them. Amazon is also launching Amazon Fresh to sell produce to consumers. Most of these initiatives are designed to increase the volume of products, particularly higher-margin items that are purchased by consumers. Retailers such as Walmart are also experimenting with the size and design of retail outlets in local neighborhoods. For example, Walmart is opening stores with smaller footprints.

EMERGING TECHNOLOGIES

3D Printing

There is little doubt that 3D printing is a transformational technology. 3D printing is different from traditional manufacturing because it creates objects by adding, rather than subtracting, material.

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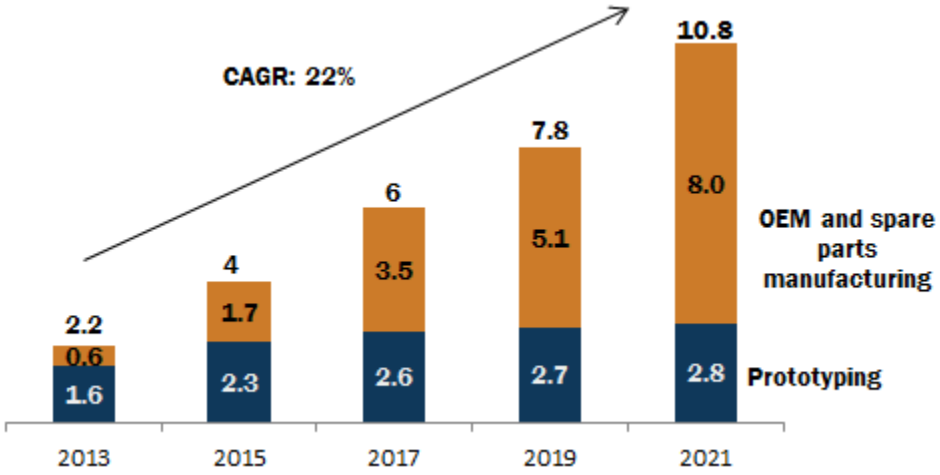
[2] Comparative advantage is an economic concept that argues that a country should focus its resources on producing only those commodities and services that it can produce more efficiently (lower opportunity cost). The commodities and services that it cannot produce as efficiently should be imported.

Boeing uses 3D printing for nearly three dozen parts on the 787, including air ducts and wiring covers. General Electric is investing $3.5 billion to revamp its aerospace supply chain, including tens of millions of dollars to triple its current 3D printing staff of 70 employees and expand its factory floor, which already contains more than 300 machines.

Figure 22 shows a predicted increasing trend in 3D printing and market adoption over the next decade. 3D printing is expected to grow and influence manufacturing, retail, consumer use, and ultimately the supply chains of these sectors.



Note: CAGR = compound annual growth rate; OEM = original equipment manufacturer.
Source: AlixPartners 2013

Figure 22. 3D Printing Marketing Forecast in Billions of U.S. Dollars.

Some of the areas that 3D printing could influence as it becomes more and more mainstream include the following.

Made-to-Order Products

It will be easier, faster, and more efficient for companies to provide made-to-order (customized) products to their end users. A classic example is iPhone cases. Many people customize their phones, and a custom-made iPhone case can be printed in about an hour. This is a better alternative for consumers than choosing from a limited collection of iPhone cases, which then need to be shipped from China over the course of six weeks (Patterson 2014).

Replacement Parts

Businesses will be able to provide replacement parts as required instead of trying to predict the need and manufacture the stock well in advance (as they do today). For example, with

3D printers, service parts engineers can download designs for spare parts and print them in a very short time. The supply of raw materials that are used to print items would need to be transported as opposed to the items, which will impact the logistics industry. The mass customization of products would mean that inventory levels will fall since goods are made to order. This could reduce warehousing requirements.

Products Made Closer to Consumers

More products will be made closer to their final destination. This will have a definite impact on the logistics industry and will change the way businesses schedule their operations (Bell 2014). Instead of outsourcing, businesses could return to nearsourcing and U.S. production. Facilities will be located closer to the consumer, allowing for a more flexible and responsive manufacturing process, as well as greater quality control. The impact of the mass availability of 3D printing on the manufacturing process could challenge the globalization of trade (Bell and Lyon 2012). 3D printing and being close to the customer will shorten the lengthy delivery process and could reduce long-haul shipping and freight forwarding. With products manufactured closer to the final destination, long trucking hours could also be significantly reduced.

More Comprehensive Services

Logistics companies could offer more comprehensive and start-to-finish services. With 3D printing technology in house, logistics companies could offer more of a fourth-party logistics (4PL) service instead of a three-party logistics (3PL) service:

- With a 3PL strategy, a logistics company only serves one specific function in the supply chain.
- With a 4PL strategy, logistics companies can manage the entire supply chain.

That means managing production, transportation, design, and more. This opportunity provides room for growth, expansion, and transformation.

Big Data

Big data is not simply defined by volume; it is also about complexity. Many small datasets that are particularly complex can be considered big data. At the same time, large

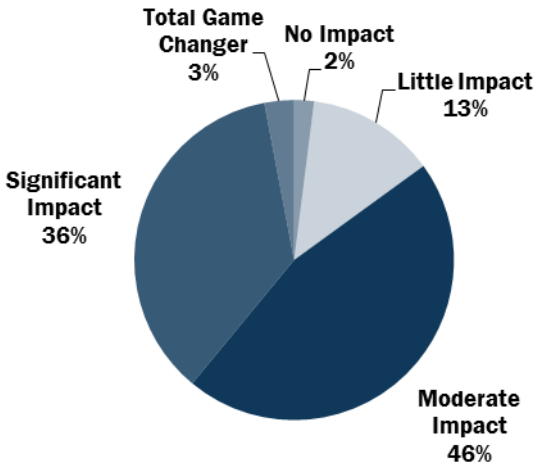
datasets may not be complex enough to be considered big data. In addition to volume, the big data label also includes data variety and velocity, with veracity sometimes added:

- *Volume* is how much data is in the dataset.
- *Variety* refers to the different types of structured and unstructured data that companies can collect, such as transaction-level data, video and audio data, or text and log files.
- *Velocity* is an indicator of how quickly the data can be made available for analysis.
- *Veracity* is an indicator of data integrity and the ability of an organization to trust the data and confidently use the data to make crucial decisions (Villanova University n.d.).

In the supply chain, manufacturing, and logistics, big data can come from point-of-sale RFID data streams, GPS data from company fleets, call center logs, consumer blogs, and online shopping habits. Leading-edge companies, such as Walmart, Zara, UPS, Tesco, Harrah's, Progressive Insurance, Capital One, Google, and eBay, have had success in their use of big data. These companies have succeeded by embracing big data using analytics to extract new insights and create new forms of value in ways that have changed markets, organizations, and business relationships.

Expectations of Big Data

The eft survey of senior supply-chain executives reported that 3 percent of the manufacturer and retailer respondents expected that big data would be a total game changer, while 36 percent expected that big data would have a significant impact on their supply chain (Reynolds 2015). Only 2 percent of the respondents reported no impact, and 13 percent reported little impact (see Figure 23).



Source: Reynolds 2015

Figure 23. Expected Impact of Big Data on Supply Chain.

Use of Analytics

Big data requires analytics to uncover information. Without analytics, big data is just a lot of data (Sanders 2014). Conversely, analytics without big data is simply mathematical and statistical tools and applications.

Status of Supply Chains. In supply chains and logistics, the most obvious use of big data is providing information about the status of supply chains in some meaningful way. Using big data and predictive algorithms, logistics providers can enhance process efficiency, and retailers can proactively manage their inventory. For example:

- Big-data-based capacity utilization predictions, such as DHL's parcel volume prediction or Transmetrics' algorithms, aim to improve the prediction accuracy of expected parcels and freight within the network.
- Amazon is exploring initiating shipments proactively before the customer even places an order, using data from different sources, such as customer product searches and shopping histories, wish lists, and even cursor activity.

Supply Chain Scenarios. Big data analytics offers critical insights, enabling companies to make better operational and strategic decisions. Big data offers the potential for optimizing capacity utilization, reducing risk, improving customer experience, and creating new business models. This entails solutions that use big data algorithms to evaluate different supply chain scenarios by anticipating potential risks. These solutions also allow service providers to select

the most appropriate scenario fitting specific customer requirements and avoid disruptions in delivery and manufacturing processes.

Rightshoring. Many companies have also used big data to design and employ a rightshoring model (Goodwill 2013). Rightshoring entails the restructuring of a global company's workforce or processes using a mix of offshoring, nearshoring, and outsourcing to achieve the optimum level of efficiency and productivity. Using big data, companies are weighing the size and location of the consumer market, the location of key vendors, distribution costs, the time to ship to market, the level of manufacturing skill required, currency, and other factors, to determine the one or more locations where their factories should be located. Unfortunately, many companies have yet to leverage big data analytics to transform their supply chain operations. Many companies have access to large quantities of data but are unsure how to use it to drive their supply chains.

Truck Platooning

Truck platooning refers to the electronic coupling of two or more trucks. The following trucks' longitudinal and lateral functions are automated to mimic that of the leading truck, while maintaining a narrow distance between them. The technology combines forward-looking radar and vehicle-to-vehicle communication that enable truck fleets to safely maneuver with a short distance between vehicles.

Figure 24 demonstrates a four-truck truck platoon tested in Japan. The reduction in aerodynamic drag for the following trucks and the buildup of pressure behind the lead vehicle yield impressive fuel savings. An ABI report noted that convoy fuel savings of 5–10 percent can be achieved (ABI Research 2015).

Source: Ashley 2013

Figure 24. Four-Truck Platoon Demonstrated in Japan.

Technology

Truck platoons are the most promising application of highly automated commercial vehicle driving in the short to medium term. Truck platoon technologies consist mostly of off-the-shelf components and are relatively straightforward to assemble. Each truck requires little more than radar-based adaptive cruise control (found in today's luxury automobiles), wireless communications with the other vehicles, and fail-safe safety algorithms and systems to handle emergencies.

ABI Research (2015) reported that more than 7 million truck platoon systems will ship by 2025. Several startup companies (e.g., Peleton) have started to market the technology along with the benefits to logistics companies with large company-owned fleets.

Benefits

Truck platooning can hold significant benefits for supply chains, specifically for the long-haul transportation of containerized goods. In addition to fuel savings, labor costs could be reduced because the follower trucks may not need drivers. Truck platooning may alleviate the driver shortage in the United States.

For short hauls and driving in an urban environment, truck platooning may not be as effective and may even be unsafe. Fuel savings may not be that significant in a slower operational environment.

Hurdles to Deployment

There are, however, several significant legal, institutional, and operational hurdles that need to be overcome before large-scale deployment and market acceptance of truck platooning can occur. For example, many U.S. states have regulations barring vehicles and trucks from driving too close to one another. Drivers operating truck platoons will also have to be trained and certified. Most transportation infrastructure (e.g., pavements and bridges) are also not designed for truck platoons. The effect on the infrastructure imposed by large numbers of truck platoons is still unknown. Figure 25 outlines the risks and barriers to the deployment of truck platoons.

Source: Robbert et al. 2015

Figure 25. Risks and Barriers to Deployment of Truck Platoons.

Automated Vehicles (Trucks)

Over the past few years, vehicle manufacturers have developed and demonstrated the use of automated vehicles (or self-driving vehicles), including automated trucks. Some have even announced that they will introduce automated vehicles to the consumer market in the near future.

Google has spearheaded this effort by introducing Google Car, which has logged more than 300,000 miles without a major incident. Similarly, Daimler Benz recently announced that it has developed an automated truck and released a video of a prototype truck with autopilot capabilities (Tschampa 2014).

Benefits

When and how automated vehicles will penetrate the consumer market are still unknown. However, the transportation sector is clear that the automated vehicle is the future and that automated vehicles will transform transportation and freight mobility. Automated trucks could result in:

- Better fuel efficiency because of a reduction in vehicle drag.
- Fewer accidents due to platoon movement over long distances.
- Lower accident-related expenses. Automated trucks could reduce or eliminate driver errors that contribute to most crashes, thereby reducing insurance premiums.
- The ability to drive longer distances because of a reduction in driver stress and fatigue.
- The ability to collect and deliver goods at off-peak hours. Automated trucks can avoid congestion during peak hours, thereby reducing fuel consumption.

Hurdles to Deployment and Challenges

In addition to technical issues, a number of legal, security, and social issues still need to be resolved. Public concerns about trucks on autopilot sharing road space and reduced employment related to driving trucks may result in political and social opposition. Also, the technology may enable people to live farther away from central business districts, aggravating urban sprawl, which could challenge logistics companies.

Transition Period

Widespread adoption of automated passenger vehicles and trucks will not happen overnight. There will be a long period of transition during which the traffic will consist of a mix of traditional and automated vehicles. Companies operating automated trucks may also choose to still employ drivers and allow the trucks to operate on autopilot under certain conditions (e.g., long stretches of highway or low-volume conditions).

CHAPTER 6:
IMPORTANCE OF TRANSPORTATION IN BUSINESS LOCATION DECISIONS

Companies make business location decisions based on several factors. Although these factors are generally similar, their relative importance may vary from company to company depending on the nature of the company's overall operations and the specific operations at a potential site. It may also vary geographically and temporally (over space and time). National Cooperative Freight Research Program Report 13 reports that supply chain and operations personnel evaluate each site location option based on the following factors (ranked in order of importance):

1. Ability to access key markets.
2. Interaction with the transportation network and modal choices.
3. Labor and workforce.
4. Total cost environment.
5. Utilities.
6. Availability of suitable facilities.
7. Permitting and regulation.
8. Tax environment.
9. Public assistance and incentives.
10. Climate and natural hazards (Steele et al. 2011).

The research team used these 10 factors as a basis for the site selection interviews conducted as part of this research study. The interviewees were asked to discuss the importance of the factor and how well Texas ranks on each. The research team specifically looked at the role transportation plays in the site selection process. This chapter summarizes the information obtained during the site selection interviews.

INTERVIEWEE SELECTION

The research team interviewed site selectors from across the United States that specialize in business location decisions for a range of industries, including manufacturing, chemical, mining, biotech, logistics, headquarters, and data centers. Specifically, the research team

identified site selectors that had experience working with Fortune 500 companies and that were knowledgeable about factors that companies consider when choosing to move their headquarters.

INTERVIEW QUESTIONS

Ten site selectors were interviewed and asked to rank the following factors, on a scale of 1 to 5, with 5 being the most important and 1 being the least important to site selection:

- Access to key markets.
- Access to transportation infrastructure/multimodal transportation.
- Labor and workforce.
- Utilities and facilities.
- Permitting and regulatory environment.
- Tax environment.
- Public assistance and incentives.
- Climate and natural hazards.

The site selectors were then asked to rank how well Texas rates on each of the identified factors on a scale of 1 to 5, where

- 1 = very poor.
- 2 = poor.
- 3 = average.
- 4 = good.
- 5 = very good.

Finally, the site selectors were asked about the reasons why a corporation would move the location of its headquarters.

INTERVIEWEE RESPONSES

Table 10 provides the responses from the 10 site selectors interviewed. Interviewees 8 and 9 did not rank the site selection factors or how Texas compares to peer states, but they provided the research team with insight into site selection and the economic development process that companies encounter when researching potential sites.

Table 10. Site Selector Interview Responses.

Interviewee	Site Selection Factor	Access to Key Markets	Access to Transportation Infrastructure/ Multimodal Transportation	Labor and Workforce	Utilities and Facilities	Permitting and Regulatory Environ-ment	Tax Environ-ment	Public Assistance and Incentives	Climate and Natural Hazards
1	Factor Importance	5	–	5	3	–	3	–	–
	Texas Ranking	–	–	–	3	–	3	3	–
2	Factor Importance	5	5	5	5	4	3	3	2
	Texas Ranking	3	3	4	–	–	–	4	–
3	Factor Importance	4	4	5	5	3	2	4	2
	Texas Ranking	4	4	4	4	3	4	2	2
4	Factor Importance	5	5	5	4	3	3	3	1
	Texas Ranking	5	5	3	3	–	3	5	–
5	Factor Importance	5	4	4	5	3	2	2	2
	Texas Ranking	4	4	4	4	3	4	3	3
6	Factor Importance	5	4	5	4	4	4	3	2
	Texas Ranking	5	5	4	4	4	4	4	3
7	Factor Importance	5	4	5	4	3	2	2	2
	Texas Ranking	4	4	3	4	4	4	3	3
8	Factor Importance	–	–	–	–	–	–	–	–
	Texas Ranking	–	–	–	–	–	–	–	–
9	Factor Importance	4	4	5	5	4	3	3	3
	Texas Ranking	3	3	4	5	4	4	3	3
10	Factor Importance	–	–	–	–	–	–	–	–
	Texas Ranking	–	–	–	–	–	–	–	–

Table 10 shows that the most important factors (i.e., tier 1 factors) in site selection are access to key markets, access to transportation infrastructure/multimodal transportation, labor and workforce, and utilities and facilities. These factors are used to narrow the potential site lists to a few areas, regions, or cities. Once these factors are satisfied, the tier 2 factors determine the ultimate site selected. These factors include the permitting and regulatory environment, tax environment, public assistance and incentives, and climate and natural hazards.

Interviewees cautioned that the importance of the identified factors differs depending on the type of industry. For example, manufacturing businesses require access to transportation infrastructure/multimodal transportation to move products efficiently. On the other hand, retail businesses may value access to key markets higher.

The following sections provide more detailed information about the importance of the tier 1 and tier 2 factors in site selection and how Texas is perceived to compare with peer states, as well as additional insight and information that were shared with the study team during the interviews.

Tier 1 Site Selection Factors

Access to Key Markets

Companies seek to facilitate the processing and movement of goods from an origin to a destination. The point of origin may be a source for raw materials, a manufacturing plant, or an intermediate point. The destination may be the ultimate consumer, a manufacturing plant, or a staging point along the supply chain. Regardless, companies typically choose locations that allow them to efficiently access these origin and key market destination points. The expectations for access are to:

- Allow fast, predictable, and precise deliveries that match or exceed the competitive standards in the market.
- Keep costs as low as possible.

For example, retailers often establish their distribution networks in a series of overlapping circles, each with a radius of approximately 500 miles. This radius allows a one-day drive from the source to the regional distribution center, a one-day drive to the local distribution center, and finally a one-day drive to the stores located in major consumption areas. Intermodal facilities and rail terminals are also located near major consumption centers but due to their size

tend to be located at the outskirts of major metropolitan areas. Also, these facilities need to be located at sites where they can generate large numbers of loads destined for destinations more than 500 miles away.

Ranking. Six site selectors ranked the factor a 5 (i.e., very important), and two site selectors ranked it a 4 (i.e., important). In regard to how Texas ranks on this factor, two site selectors ranked Texas a 5 (i.e., very good), three site selectors ranked Texas a 4 (i.e., good), and two site selectors ranked Texas 3 (i.e., average).

Comments. Interviewees commented that:

- Many suppliers want to be within two hours of key markets.
- Manufacturing and distribution companies want to be within a one-day delivery by truck of the majority of their markets and a two-day delivery for almost all of their markets.
- Access to markets is critical for an office, information technology (IT) company, or service center.
- Access to markets can be the most significant factor for a growing company.

Some respondents remarked that Texas ranked well because the state has a large population with sizable urban markets and is close to Mexico and the southeastern part of the United States. Also, Texas was ranked high because of access to Midwest markets but ranked poorly for New York or California markets.

Access to Transportation Infrastructure/Multimodal Transportation

Besides proximity and access to customers and markets, companies need efficient access to a regional transportation system. Depending on the facility type and the markets to be served, access to more than one mode of transportation may be required because it provides a choice about how to move goods. Companies looking for locations know their transportation needs and the expected transportation costs. Communities that successfully attract businesses are able to facilitate efficient access to points of production or ports of entry and consumers. Sites that provide access to major highways (or where multiple interstate highways converge), railroad terminals, and major sea and airports are desirable.

However, community issues can prevent or inhibit effective use of the site, even if it is set in precisely the right location in terms of transportation access. Distribution centers, for

example, usually need to operate on a 24-hour basis, yet a community may have regulations that restrict hours of operation or prohibit truck traffic on an access road.

Mode-choice requirements are typically determined by the type of commodity, transportation costs, reliability, and travel time. These factors can vary greatly by mode and region, depending on the transportation infrastructure, available transportation service providers, size of the market, and quality of freight transportation service. The ultimate mode preferences may include any combination of truck, rail, water, or air.

Ranking. Two site selectors ranked the factor a 5, and five site selectors ranked it a 4. In regard to how Texas ranks on this factor, two site selectors ranked Texas a 5, three site selectors ranked Texas a 4, and two site selectors ranked Texas a 3.

Comments. Interviewees commented that:

- Transportation needs are determined by the type of company. For example, an asphalt company needs access to rail, and it would be the most critical factor for that company when selecting a business site.
- Companies want to be close (within 10 miles) to a limited-access, four-lane highway, and 10–15 percent of industrial companies need access to rail. An estimated 30 percent of industrial companies need to be within a six-hour drive of a port. In general, companies want a good choice of truck-load and less-than-truck-load terminals within a 45-minute drive.
- Logistics is an important factor, with connectivity and access to infrastructure being most crucial. The primary focus of logistics is railroad and roadway connectivity.

Concerning Texas, the site selectors interviewed commented that:

- Texas ranked average on access to transportation infrastructure/multimodal transportation.
- Texas has great transportation logistics infrastructure but needs to increase infrastructure funding and maintenance.
- Dallas ranked well because is it very accessible to airports, rail, and highway infrastructure, and many warehouse distribution centers are located in the area.

Labor and Workforce

Every company/industry is different, but access to labor skills, labor cost, and the overall workforce environment play a key role in site selection. While a few industries are highly automated or do not have high labor skill requirements, others involve assembly, manufacturing, value-added processing, or other operations where the availability of a trained labor pool is an important requirement.

For example, one of the site selectors interviewed noted that potential sites can be divided into customer service and industrial facilities. For customer service sites, a skilled workforce is required, but for industrial facilities, infrastructure is ranked higher than workforce availability. Some companies/industries also require a wide range of labor skills, depending on the exact nature of the facility. Companies examine labor data for the region or community to evaluate the quality, quantity, and proximity (accessibility) of the available labor pool to potential sites.

Ranking. The ability to attract and hire a skilled workforce received the highest ranking among the interviewees. Seven site selectors ranked the factor a 5, and one site selector ranked it a 4. In regard to how Texas ranks on this factor, five site selectors ranked Texas a 4, and two site selectors ranked Texas a 3.

Comments. The site selectors interviewed commented that:

- Companies identify a search region(s) and within the region(s) look at labor and other factors to narrow down specific locations. Workforce becomes a critical factor once the search region has been selected. Site selectors narrow down potential sites based on the labor supply. Skilled laborers such as machinists, welders, and electricians can be in short supply.
- Site selectors meet with local community colleges to assess workforce skills and rank cities based on their future workforce development plans.

The site selectors ranked Texas very differently in terms of access to labor and workforce availability. One site selector remarked that Texas ranks well in terms of labor availability, cost, and quality. Another site selector remarked that Texas' labor force is "pretty good," but it could improve with more technical education. Additionally, another site selector felt that Texas' labor is not as skilled as that in other areas such as Boston or Silicon Valley, specifically in biomedical or engineering skills. Finally, a site selector ranked Texas high for the quality of labor but ranked Texas lower for availability of labor. A lower availability of labor can result in bidding wars and

higher labor costs for companies. These views are largely a reflection of the type of company/industry specialization of the site selectors interviewed.

Utilities and Facilities

Companies consider a site that is competitively priced but only if the site satisfies the key criteria. For example, the availability of well-planned warehouse space at a regional airport will be considered if that airport also has good highway access and allows unimpeded service to key market areas. On the other hand, a lack of suitable facilities on land zoned for industrial or commercial uses near key infrastructure can impede progress or remove a region/site from consideration. It is common for carriers siting city terminals to limit their site search to existing industrial facilities because of the cost of new construction and concern about community resistance (which can delay the project and increase costs). These kinds of properties become available as leases expire and leasers grow, consolidate, or fail.

Companies seek buildings of a particular size envelope, layout, ceiling height, number of loading docks, floor loading limits, utility feeds, refrigerated space, purchase price, rent and operating costs, and other attributes depending upon their specific requirements. For example, warehouses with modern, automated material-handling equipment allow for additional capacity vertically—toward the ceiling—instead of horizontally, which adds to square footage and lease costs. Alternatively, companies may seek land near specific transportation infrastructure or other supply chain partners. Operations such as bulk and transload facilities allow for consolidation and typically require access to rail and marine vessels.

In the ultimate location decision, a company wants to be assured that reliable and cost-effective electricity, water, sewer, and other utility capacity exist. Some companies/industries are also more dependent on utility capacity than others. For example, electric, water, and sewer capacity is less critical to warehouse, distribution center, and intermodal facility locations than for data center and manufacturing companies. Similarly, refrigerated and automated warehouses (which are highly reliant on computerized machinery) have requirements concerning the amount, cost, and reliability of electricity. Specifically, companies/industries that use heavy lift and computerized machinery may even consider access to uninterrupted electricity critical when evaluating potential sites.

Ranking. Available facilities and utilities ranked equally high compared to access to key markets, access to transportation infrastructure/multimodal transportation, and labor and workforce. Four site selectors ranked the factor a 5, three site selectors ranked it a 4, and one site selector ranked it a 3. In regard to how Texas ranks on this factor, one site selector ranked Texas a 5, four site selectors ranked Texas a 4, and two site selectors ranked Texas a 3.

Comments. The site selectors noted that over the past five years, some manufacturing companies have sought sites with existing utilities, while others have sought shovel-ready locations so they can build their own facilities. In general, Texas was noted as a large state with many facilities and a good variety of facilities available. One site selector, however, noted that Texas does not have a certified site program, which analyzes potential sites and provides information on the facilities and permitting process.

Tier 2 Site Selection Factors

Permitting and Regulatory Environment

The permitting and regulatory environment determines how a company can implement its plans for a particular site and timeline. If a region or city is familiar and has experience (e.g., has a process) with locating industrial and freight facilities, it can be viewed as a location advantage. As such, the content and interpretation of fire codes, land use regulations, traffic regulations, zoning, and hour-of-operation regulations can all impact the feasibility of locating the company/industry at a specific site.

Ranking. The factor of permitting and the regulatory environment was ranked the highest of the tier 2 factors. Three site selectors ranked the factor a 4, and four site selectors ranked it a 3. In regard to how Texas ranks on this factor, three site selectors ranked Texas a 4, and two site selectors ranked Texas a 3.

Comments. The site selectors commented that anything a state or city can do to speed up the permitting process is beneficial. It is important for companies/industries to have information about the environmental situation at the site because a delay in the permitting delays the overall project. It is also important whether the site is in an attainment or nonattainment area. If the site is in a nonattainment area, the costs could increase for the company.

In general, Texas was viewed favorably in terms of both permitting costs and the permitting timeline. One site selector noted that the regulatory environment is not overly

burdensome. One site selector, however, did note that the permitting process is easier in Louisiana.

Tax Environment

Income, sales, real estate, and state property taxes are all components of the tax environment companies/industries consider when locating facilities. For example, real estate taxes can be high in urban areas, especially if the land can be used for other high-density development, such as upscale condos and retail. High real estate taxes may result in freight facilities being developed on the urban fringe. High personal property taxes are also a concern if inventory is taxed as personal property.

Ranking. The site selectors ranked the tax environment less important. One site selector ranked the factor a 4, four site selectors ranked it a 3, and three site selectors ranked it a 2. In regard to how Texas ranks on this factor, five site selectors ranked Texas a 4, and two site selectors ranked it a 3.

Comments. Two of the site selectors interviewed noted that taxes are generally perceived to be higher and more important than they really are. It is more of a perception issue. Federal taxes, on the other hand, are an important consideration in determining if a company will locate in the United States or overseas. Multi-state companies can manage an income tax liability by shifting resources.

The perception of Texas' tax environment varied depending on the type of company/industry. One site selector noted that Texas offers a favorable tax climate for companies that do not ship a large amount of products (because of the inventory tax levied) or have a lot of office space (because of high sales and real estate taxes). In other words, Texas provides a good tax environment for service businesses that do not occupy large properties. Texas has no income tax, which helps attract people, but it has high real estate, sales, and franchise taxes.

Public Assistance and Incentives

Public-sector assistance in the form of tax credits, grants, low-cost loans, training programs, utility discounts, and infrastructure development incentives is often used by a region or city to gain an advantage over a competitor. When competing sites are rated relatively equal, incentives offered by the public sector may close the deal.

Ranking. The site selectors ranked public assistance and incentives similar to the tax environment. One site selector ranked the factor a 4, four site selectors ranked it a 3, and two site selectors ranked it a 2. In regard to how Texas ranks on this factor, one site selector ranked Texas a 5, two site selectors ranked Texas a 4, four site selectors ranked Texas a 3, and one site selector ranked Texas a 2.

Comments. One site selector noted that companies like the idea of incentives, but another noted that if the incentives are large but the taxes are high, it will be a less favorable site.

The site selectors ranked Texas very high in terms of offering incentives, and one site selector attributed Texas' pro-business climate to Governor Perry's efforts. On the other hand, one site selector noted that the application process and paperwork are extremely tedious in Texas. He offered an example in Harris County where the application was 200 pages. Similarly, the Texas Enterprise Fund application is very long, and the process takes months compared to weeks in peer states. One site selector noted that the Texas Enterprise Fund needs a minimum of $150 million to make a difference.

Climate and Natural Hazards

To understand the potential risk of interruptions, companies/industries collect historic data on the region's climate and natural hazards to determine how they have impacted business closures in past years. Companies sometimes compile data on excessive heat, cold, rain, snowfall, earthquakes, wildfires, tornadoes, and hurricanes to develop appropriate planning, response, mitigation, and recovery plans. Few regions/areas are without some form of natural hazard risk.

Ranking. The site selectors noted that the potential impacts from climate or weather events such as floods, droughts, hurricanes, or tornadoes are the least important in site selection decisions. One site selector ranked the factor a 3, five site selectors ranked it a 2, and one site selector ranked it a 1. In regard to how Texas ranks on this factor, four site selectors ranked Texas a 3, and one site selector ranked Texas a 2.

Comments. One site selector noted that weather considerations sometimes play a role when companies that are more risk averse need to decide on the location of a data center. Some companies also might not want to deal with the snow in the northeast or hurricanes along the coast. It is rare for a company to dismiss a site solely based on climate considerations. On the

other hand, climate and natural hazard considerations have become more important for insurance purposes after Hurricanes Rita and Katrina. In general, the site selectors interviewed did not feel that climate and natural hazards were a major factor in Texas. Only one site selector noted that the drought is a consideration for projects that need large quantities of water, such as food processing.

Headquarter Relocation

The research team asked all the site selectors interviewed to state the reasons for companies to relocate their headquarters. Most interviewed stated that companies rarely relocate because moving is expensive—it is never a cost saving to relocate headquarters—and they risk losing staff. It is also difficult to quantify the benefits of moving locations. In some cases, companies move because cities offer incentives for major headquarters. For example, Atlanta has been very aggressive in attracting headquarters.

All interviewees stated that the reason companies relocate their headquarters is access to an international airport with nonstop flights to Asia and Latin America, as well as frequent flights to Europe. In Texas, Houston and Dallas have good international air service, but Austin and San Antonio have limited direct international air service. Other reasons offered for companies to relocate their headquarters are the following:

- Businesses change over time so that a company may want to locate to an area with similar industries.
- Being located in an industry cluster provides opportunities to share ideas and attract talent.
- Companies move to attract better talent or a more skilled labor force. A rural area might not provide the talent needed to support a company, or the company may want to improve the quality of life of employees. Companies look for a site with good schools and affordable housing.
- International companies may want a U.S. presence.
- A merger of companies may require the headquarters to be consolidated.
- Companies may want to be closer to customers or the production and supply chain.
- California companies relocate because they are frustrated with the business climate, costs, and high income taxes.

CHAPTER 7:
CHANGING BUSINESS MODELS

The demand for freight transportation is derived from the need to move products/commodities from production to consumption points/centers through the supply chain. Freight transportation connects businesses to their supply chain partners and ultimately to their customers. Efficient and effective freight transportation can also differentiate a company from its competition and result in a more competitive business.

To understand the role of transportation in a business, it is first necessary to understand the company's business model. The study team interviewed 30 representatives of major U.S. and Mexican companies to gain a better understanding of their business models and the associated requirements of the freight transportation system in Texas. This chapter discusses the changing business models that are emerging based on the literature reviewed and the information shared with the study team during the interviews.

JUST-IN-TIME BUSINESS MODEL

The just-in-time (JIT) business model originated in Japan in the 1950s. JIT is an operations management approach that reduces in-process inventories and their associated costs in an effort to maximize a business's return on investment. The benefits from JIT have been well documented over the years, including lower inventory investment and associated warehouse savings (Wilkinson 1989). For example, Lambert and Stock (2000) compared the value of the work-in-process inventory of $775 per car carried by U.S. automakers to the $150 carried by Japanese automakers in the 1980s. This resulted in U.S. automakers adopting JIT philosophies and total quality management programs, which have since evolved into International Organization for Standardization 9000, Lean, Kaizen, Six Sigma, and other variations of continuous improvement of operations management approaches. General Motors, for example, reduced its freight inventory by 17 percent five years after implementing JIT (Uribe 1986).

Partnerships with single-source suppliers of quality materials are optimal for JIT to reduce costs. Often, JIT results in suppliers locating, for example, near the automobile assembly plants to facilitate frequent deliveries of small shipments (Evans and Lindsay 1993). The structure of the JIT business model is changing from waste reduction and smooth-running assembly lines to a demand-responsive approach that includes next- and same-day order

fulfillment. According to executives interviewed from the automotive industry in Mexico, the vision is to implement direct pull orders in real time from the point of sale through each component of the supply chain. This will require suppliers to have inventories located closer to the manufacturer to allow for the receipt of smaller deliveries of raw materials on a more frequent basis.

This agglomeration of industries will increase the development of clusters (e.g., in this case the automotive cluster). Clusters offer economic and competitive advantages, such as reduced financial and transportation costs, easier knowledge transfer, and a larger pool of specialized workers (Krugman 1991). The development of economic clusters such as Hollywood or Bollywood in the film industry, the wine industry in California, and IT in Silicon Valley, Austin, and Boston is expected to continue. Ultimately, the goals are to maximize flexibility and minimize inventories throughout the JIT supply chain.

OUTSOURCING, NEARSOURCING, AND INSOURCING

Definition

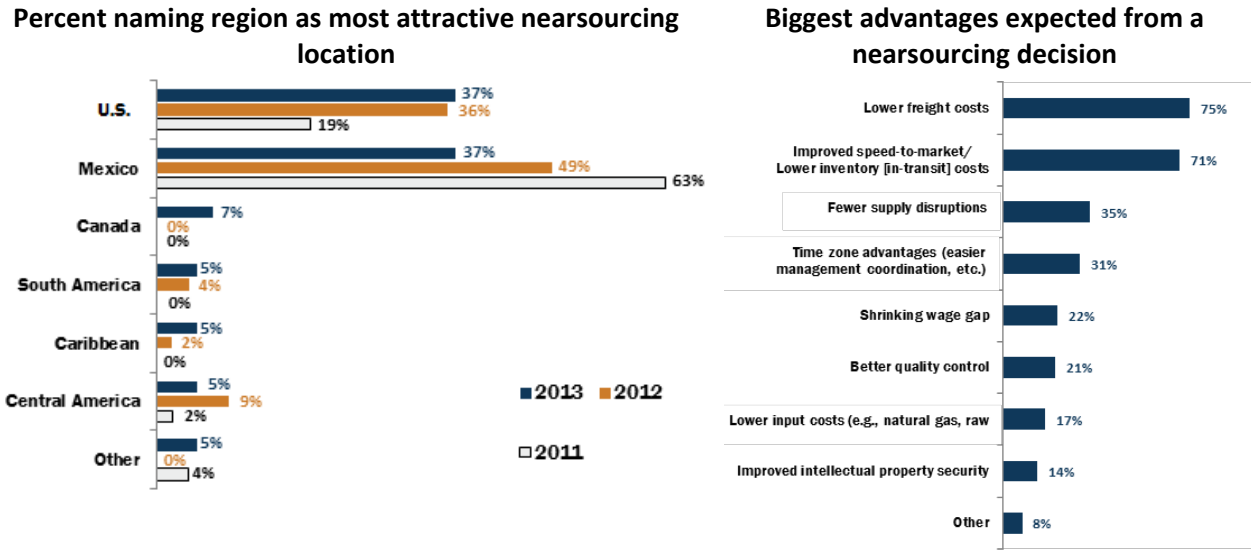
Outsourcing is defined as the procurement of goods or services from an outside supplier. Outsourced manufacturing now represents about one-third of the global production of electronics, and approximately 46 percent of outsourced electronics manufacturing is done in China (Wallingford and Keith n.d.). The changing environment in emerging markets—once considered lower-cost production countries—is making outsourcing decisions more complex. Specifically, increases in labor, logistics, financing, tax, and shipping and logistics costs will making outsourcing less economically attractive.

Nearsourcing (or nearshoring) is the assignment of a business process or service to a "foreign, lower-wage country that is relatively close in distance or time zone (or both)" (Carmel and Abbott 2007)." The benefits of nearsouring include shorter distances, fewer time zones, and cultural, linguistic, economic, political, and historical linkages.

Insourcing occurs when a U.S. company decides to terminate an outsourced product or service relationship and to manufacture a product or procure a service internally from a U.S. location. Insourcing is the opposite of outsourcing.

Preferred Location

According to the AlixPartners (2013) Manufacturing-Sourcing Outlook, an online survey of 137 executives from more than 10 industries indicated that 37 percent would prefer to locate in the United States (*insourcing*)—the same percentage that would prefer to locate in Mexico (*nearsourcing*). For 84 percent of the responding executives, the decision to nearshore is very important or somewhat important—an increase of 31 percent relative to 2012. Nearsourcing is perceived as an opportunity to meet U.S. demand by 49 percent of the respondents. Of this 49 percent, one-third are nearsourcing or have already nearsourced, and 57 percent have plans to do so within one to three years (AlixPartners 2013). Figure 26 displays the results for two of the questions included in the Manufacturing-Sourcing Outlook survey.



Source: AlixPartners 2013

Figure 26. AlixPartners Manufacturing-Sourcing Outlook Survey.

A survey conducted by MFG.com found that 21 percent of North American manufacturers reported nearsourcing activities within the past three months—9 percent more than in the previous quarter (Costanzo 2014). These survey results can be partly explained by the fact that shipping costs are becoming increasingly important for a company's business competitiveness. In the 2013 Corporate Survey, one transportation-related factor showed the second-largest increase in importance (gaining 12.8 percent): proximity to suppliers. Although this factor maintained its 19th position in the rankings, it is now considered "very important" or "important" by more than two-thirds of the Corporate Survey respondents.

Transportation Network

Among the several advantages of nearsourcing to Mexico reported by Costanzo (2014), a connected transportation network of road, rail, air, and water options presents the backbone of an improved supply chain serving NAFTA trade. Moreover, familiarity with the border-crossing process facilitates pre-cleared shipments for entry. However, Costanzo (2014) recognizes the investments needed in the crumbling infrastructure of the United States, Mexico, and Canada to make nearsourcing more attractive.

Labor

An online survey of almost 1,000 executives conducted by Deloitte reported that 50 percent of the respondents answered that increased competition for labor was the biggest challenge for operations in China, and 13 percent responded rising costs. Although most U.S. companies already nearshore with operations in Canada, Mexico, and Brazil, 50 percent of the respondents to the Deloitte survey reported that they are most likely to deploy their next manufacturing operations to another country within Asia, and 20 percent will most likely deploy to the United States. For service centers, India remains the preferred location for 41 percent of the respondents, followed by the United States for 31 percent of the respondents (Deloitte Development, LLC, 2014).

OMNI-CHANNEL COMMERCE

In the last decade, global e-commerce and retail competition have increased the choices consumers have both online and in brick-and-mortar stores.[3] Omni-channel[4] commerce is driving a new set of logistics and fulfillment challenges, adding to the complexity of supply chain management. Supply chain management and 3PLs must now be able to capture customer orders from all channels (e.g., online and brick-and-mortar stores), complete fulfillment, and distribute to all channels simultaneously (Cadre Technologies 2014).

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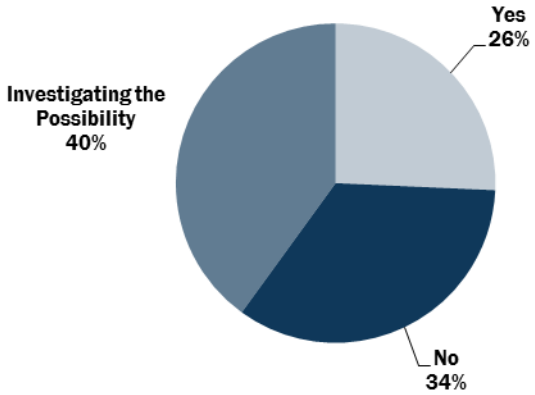
[3] Retail conducted in physical buildings or facilities.

[4] *Omni-channel commerce* can be defined as retailing to the consumer through a variety of mediums, including mobile devices, the Internet, brick-and-mortar stores, television, radio, and mail advertisements.

Plans to Expand Omni-channel Commerce

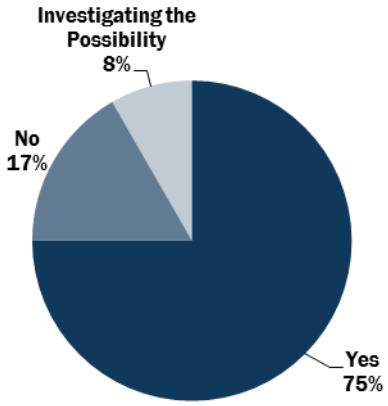
The eft survey of senior supply chain executives reported the responses of manufacturers and retailers to the question of whether they have plans to expand their omni-channel capabilities in the short term (i.e., 12 months). Figure 27 and Figure 28 show that:

- 26 percent of the manufacturer executives and 75 percent of the retailer executives had plans to expand their omni-channel capabilities.
- 40 percent of the manufacturer executives and 8 percent of the retailer executives were investigating the possibility of expanding their omni-channel capabilities.
- 34 percent of the manufacturer executives and 17 percent of the retailer executives had no plans to expand their omni-channel capabilities.



Source: Reynolds 2015

Figure 27. Short-Term Plans to Expand Omni-channel Capabilities: Manufacturer Perspective.

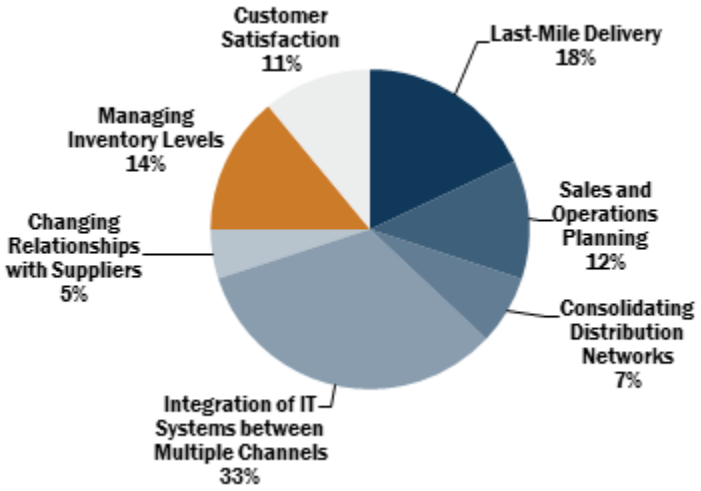


Source: Reynolds 2015

Figure 28. Short-Term Plans to Expand Omni-channel Capabilities: Retailer Perspective.

Biggest Concern When Expanding

Questions are emerging regarding the location, design, and layout of distribution or fulfillment centers to facilitate omni-channel capabilities. In the eft survey of senior supply chain executives, respondents were asked to indicate the biggest concern when expanding omni-channel operations. Figure 29 shows that last-mile delivery was the second most reported concern (18 percent of the respondents reported last-mile delivery as the biggest concern) after integration of IT systems between multiple channels, which was reported by 33 percent of the respondents as their biggest concern in expanding omni-channel operations.

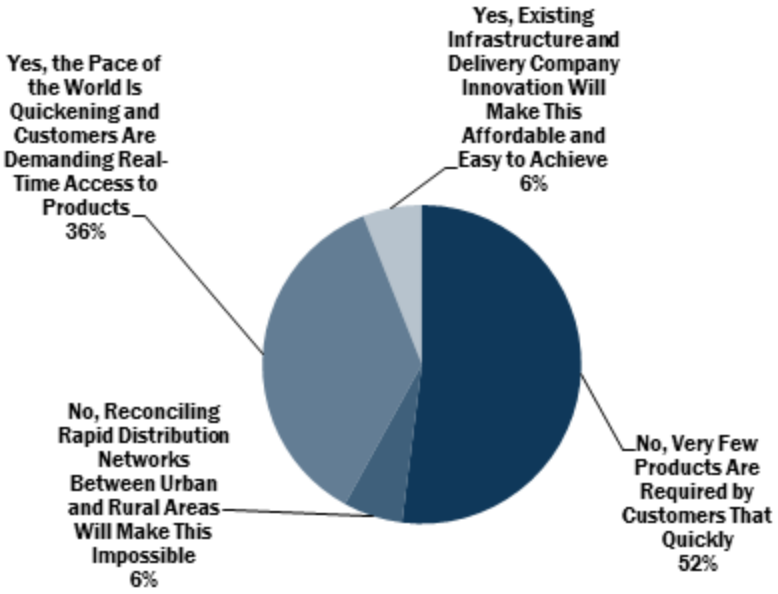


Source: Reynolds 2015

Figure 29. Biggest Concerns in Expanding Omni-channel Operations.

Same-Day Deliveries

Moreover, questions are emerging about required strategies, processes, and technologies for next-day, same-day, and in-store deliveries. In the eft survey of senior supply chain executives, 42 percent of the respondents indicated that same-day delivery is inevitable because the pace of the world is quickening (36 percent of the respondents) and because innovation will make same-day delivery affordable and easy to achieve (6 percent of the respondents) (see Figure 30).



Source: Reynolds 2015

Figure 30. Whether Same-Day Delivery Is Inevitable.

To fully serve omni-channel operations efficiently, 3PLs and JIT supply chains will need to handle inventory, shipments, and order fulfillment to all channels under the same roof and closer to the end customer. For example, Amazon, the largest e-commerce retailer, has invested $13.9 billion since 2010 to build 50 new warehouses to reach a total of 89—more than in the last 10 years combined—to fulfill same-day deliveries (Kucera 2013).

GREEN SUPPLY CHAINS

The Relationship between Profitability and Sustainability

Much of the literature regarding green supply chains and the associated business models focus on the relationship between profit and sustainability. A green supply chain aims to achieve triple bottom line sustainability: financial, social, and environmental (Elkington 1999, Kleindorfer et al. 2005). For example, Iannone (2012) reported that the key objective of green freight logistics systems is to mitigate the negative environmental and human health effects of distribution operations while maintaining quality of service and cost efficiency.

Agell and Wu (2009) conducted 10 case studies of exemplary firms, complemented with previous research, to build a model and more complete theory of sustainable supply chain management. All 10 firms were found to harm the natural or social systems, but some companies

were found to be more sustainable than others. The research noted that the more sustainable firms usually continue to be in business longer than their average competitor.

Emissions Standards

As the adoption of sustainability initiatives that support a low-carbon economy becomes more necessary to combat climate change, the pressure on companies to reduce the carbon footprint of their supply chain will increase.

For example, in the last decade, the World Resources Institute and the United Nations have launched several initiatives, including formal carbon emission standards. These include the Greenhouse Gas (GHG) Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard, and the Product Lifecycle Standards (World Resources Institute 2011a; World Resources Institute 2011b). According to Scope 3, "global carbon dioxide emissions must be cut by as much as 85 percent below 2000 levels by 2050 to limit global mean temperature increase to 2 degrees Celsius above pre-industrial levels." Scope 3 outlines the accounting principles to measure, manage, and report GHG emissions. Since about 75 percent of a company's carbon footprint is related to transportation and logistics, this component of the supply chain will be increasingly scrutinized (Logility n.d.).

Company Sustainability Initiatives

At the company level, typical sustainability initiatives include the optimization of inbound and outbound transportation routes, the maximization of truck and container capacity, and cross-docking opportunities and consolidation of multiple orders. During the last decade, the introduction of transportation management systems has assisted companies to reduce transportation costs, enabling companies to go green by reducing fuel consumption and lowering emissions. These initiatives increase a company's competitive advantage while reducing the impact of logistics activities on the environment. According to a joint study by several universities in the United States and Hong Kong, "determining how frequently supply deliveries are made could be as important in mitigating carbon emissions as the energy efficiency of the vehicles used to make these deliveries" (Benjaafar et al. 2013). This study argued that certain popular business practices, including JIT and lean manufacturing, with their frequent delivery requirements, could increase carbon emissions.

More green companies and technological innovations are also expected to integrate into future supply chains. Numerous manufacturers are testing autonomous and driverless systems for freight movement—some with zero carbon emissions. For example, Rio Tinto, a British mining corporation, is using 10 self-driving ore trucks and is planning to buy another 140 vehicles (The Economist 2012). Zero carbon emission vehicles are expected to move freight in a cleaner, greener, and more efficient way than is currently available.

COLLABORATE TO COMPETE

Collaborate to compete is a business model that recognizes the insufficiency of individual efforts in tackling complex problems. In a public-sector context, this could mean collaboration of unlikely partners (e.g., the county authority and the business community, or regional hospitals and universities) to build infrastructure that will promote common goals and generate a collective impact (Hecht 2013). In a private-sector/commercial context, this means collaborating to save costs, increase investment, and expand research and development.

The idea that "companies need to out-compete in order to out-perform" is becoming obsolete (Lowitt 2012). As economies become more complex and as companies are increasingly being held accountable for their business practices, companies need a wide range of skills to succeed. Therefore, the realization that an individual company cannot have all the knowledge, personnel, systems, suppliers, customers, and relationships it needs to succeed has resulted in collaboration among rival companies. Technology has both facilitated such coordination and increased the need for it by bringing global competition closer. Collaboration across companies creates a model that is difficult for competitors to emulate and so delivers a competitive advantage (Carney n.d.).

The collaborate-to-compete concept as it applies to resource sharing also applies to economic or industry clusters. The Toronto Region Board of Trade identifies economic clusters as a means of embracing the collaborate-to-compete concept and moving toward an integrated economic strategy for the region. These clusters benefit from companies locating in close geographic proximity and allow them to collaborate to address common challenges. Economic clusters promote innovation in addition to increased production. Ideally, such economic clusters foster mentorship, allow for collaboration in research and development between universities and

businesses, foster access to advanced digital and physical infrastructure, attract investment, and position companies in the global market (Toronto Region Board of Trade n.d.).

The following are a number of examples of collaboration among competitors:

- Nestle Waters North America collects recycled plastic to produce its water bottles. Since less than 30 percent of plastic is recycled and collected from consumers, the company is putting together a group of competitors that will collaborate to address the problem of an ineffective recycling system (Lowitt 2012).
- Comite Colbert is an association of 75 companies in the luxury goods sector. Through this association members "share good practices, exchange prospective information on the luxury goods sector and its trends, and work together to innovate" (Turiera and Cros 2013). Members meet throughout the year and explore future options for developing sustainable initiatives and penetrating new markets (Turiera and Cros 2013).
- The Sustainable Apparel Coalition consists of companies and individuals in the apparel sector. The coalition's goal is to reduce the social and environmental impact of apparel products. One of its initiatives is the Sustainable Apparel Index, which provides directives and recommendations, and metrics on consumption of resources, waste, and emissions. The coalition has more than 35 members including Adidas, New Balance, Nike, and Patagonia. The index has not only resulted in cost savings for member companies but has also reduced the companies' environmental impact and improved their risk management and reputation (Turiera and Cros 2013).
- CaseStack, Inc., an online logistics services supplier in the United States, has relationships with warehouses and trucking companies and provides outsourced logistics for small and midsize companies. The company allows its customers to consolidate loads with other shippers so trucks arriving at a store have a full load for that store, which is particularly important in the grocery sector where full loads are given priority (Babcock and Dunn 2003).

DHL reported that technological change will be achieved through a concerted drive from companies, financial institutions, and governments. Collaboration and support among stakeholders will be key because new technologies are costly. Furthermore, collaboration will become increasingly important for sustainability. As carbon emission reduction becomes a

priority for suppliers, business customers, and logistics companies, cooperative business models will expand both vertically and horizontally along the supply chain (Deutsche Post DHL 2012).

CHAPTER 8:
FREIGHT 2055 FRAMEWORK

The study team hosted a one-day workshop to review the major factors and trends that could impact the requirements of Texas businesses for a future freight transportation system, and to discuss the role of TxDOT in conducting proactive freight planning that will support the future growth of industry and ultimately of the Texas economy. The Freight 2055 Roundtable was hosted at the North Central Texas Council of Governments in Arlington on Wednesday, July 8, 2015.

The study team and TxDOT invited a diverse group of freight stakeholders that represented both the public and private sectors. Email invitations were sent to approximately 700 freight stakeholders. In total, 85 stakeholders participated in the roundtable. Participants included representatives from ports, rail, highways, cities, corporations, metropolitan planning organizations, logistics service providers, engineering and planning firms, consulting firms, and academia. A separate deliverable (0-6089-P2) was published that provides a detailed summary of the Freight 2055 Roundtable discussion. Roundtable participants offered a number of suggestions and recommendations to frame the role of TxDOT in preparing the Texas freight transportation system for 2055. Four themes emerged from these suggestions and recommendations that provide a framework for the role of TxDOT in preparing for freight in 2055:

- Facilitate/manage Texas' freight transportation system.
- Pilot innovative freight policies/technologies.
- Serve as a freight data clearinghouse.
- Educate and reach out to the public, legislators, and freight stakeholders.

These four themes, which at times are related and often overlap, are documented and discussed in this chapter.

FACILITATE/MANAGE TEXAS' FREIGHT TRANSPORTATION SYSTEM

Under this theme, a number of sub-themes/strategies emerged that describe the future role freight stakeholders are expecting of the state's transportation planning agency:

- Become a multimodal transportation agency that advocates for all freight modes.
- Provide funding for all freight modes.

- Focus on connectivity projects (not only congestion).
- Facilitate among different agencies and the public and private sectors to advance freight projects.

Multimodal Transportation Agency

The Freight 2055 Roundtable discussion revealed that freight stakeholders in the state expect TxDOT to continue to evolve into a multimodal transportation agency that advocates for all modes of freight transportation (not only highways). Although TxDOT has made strides in evolving into a multimodal agency with the formation of the Rail Division, Port Division, and more recently the Office of Freight and International Trade, most stakeholders felt that the agency is still largely focused on the development of the highway system.

It was recommended that the private-sector freight rail companies be included early on in the discussion of proposed transportation projects that impact the rail sector. More collaboration with the private-sector rail companies is needed, but this requires a mutually trusting environment (i.e., no hidden agendas and a transparent transportation agency).

The roundtable participants specifically pointed out that maritime transportation should be of greater concern to TxDOT. TxDOT should recognize that ports are part of the multimodal solution and should assist the ports in competing with ports in other regions and states. Participants also highlighted the importance of the Gulf Intracoastal Waterway but indicated that it is constantly underfunded, and the infrastructure (e.g., dredging and locks) is always insufficient.

Similarly, participants that represented the border regions argued that border crossings should be considered part of the multimodal solution. With anticipated increases in trade with Mexico, it was considered critical that ports of entry do not become major bottlenecks and impede trade.

Multimodal Transportation Funding

TxDOT, like many other state departments of transportation, is increasingly challenged by inadequate funding to increase transportation system capacity while maintaining the existing transportation system. Participants stressed the need for a dedicated, recurring freight funding source in the short to medium term.

Oregon's Connect Oregon Program serves as an example of a dedicated freight funding program. Oregon allocates $45 million per year to freight projects to serve as a catalyst for freight investments. It is in essence a state-level Transportation Investment Generating Economic Recovery (TIGER) program. The funding is obtained from lottery-backed bonds. The Connect Oregon Program identifies needs, establishes a planning framework, and aims to overcome the silo-based planning approach so common in freight planning.

Roundtable participants indicated that they expect TxDOT to seek additional funding for the freight transportation system and to develop support for new funding sources because the gas tax and tolls are not adequate. It was recommended that by 2055 TxDOT support more private-sector investment in highway infrastructure, take advantage of public-private partnerships and TIGER grants, and use user fees to support the development of transportation infrastructure. The rail sector, in particular, continues to support the user-pays principle—where the user pays for infrastructure usage—to fund freight infrastructure.

Participants agreed that freight investments should be a priority. Specifically, it was suggested that TxDOT assist the ports with obtaining funding for dredging, and that TxDOT invest in connectors between major freight generators (e.g., ports, border crossings, and major distribution centers) and the rest of the network.

Some of the constraints include the following:

- The Texas Legislature currently needs to vote on every Comprehensive Development Agreement that TxDOT enters into with the private sector. This limits the potential for significant growth in private-sector investment in highway infrastructure.
- The Highway Fund 6 can only be used for highway projects. The Texas Rail and Reinvestment Fund has not been capitalized. Similarly, no funding has been appropriated to the Port Access Account Fund that was established by the Texas Legislature in 2001. It is also often politically difficult to invest public money in a private rail company.

Focus on Connectivity

The Freight 2055 Roundtable discussion revealed that local agencies expect to have a greater mandate for all aspects of the freight transportation system in their regions in the future, including planning, funding allocation, and, to some extent, implementation. TxDOT's role is expected to evolve into coordination with a focus on interregional connectivity, redundancy in

the freight system, and last-mile connectivity. Interregional connectivity entails connectivity between urban and rural areas, between Texas and neighboring U.S. states, between Texas and Mexico, and between the various freight modes that operate in the state. For example, TxDOT needs to focus on connections to the ports and connections with other modes. Similarly, TxDOT needs to focus on highways that support rural connectivity to urban areas. Many of these highways are Interstate Highways and some carry as much freight tonnage as the major highways in the urban areas. A good example of an Interstate Highway that carries a significant amoung of freight tonnage in a rural area is IH 40 through the Texas Panhandle.

Facilitator among Public and Private Sectors

As the state transportation planning agency for Texas, TxDOT works with transportation stakeholders at the local, state, and federal level to coordinate planning and funding of Texas' transportation system with an emphasis on the state-maintained highway system. TxDOT also has a Local Government Projects Office that facilitates between the federal government and local jurisdictions (TxDOT n.d.). The duties of this office include assisting local governments, such as municipalities, counties, or regional mobility authorities, in navigating the requirements to use federal highway funding for non-TxDOT-maintained facilities. The office also provides assistance and training for local governments. The responsibility of local governments is to ensure that all requirements of the project are identified and federal funding agreement provisions are met.

Participants, however, stressed that TxDOT's primary responsibility is still to the maintenance and building of highway capacity. Freight 2055 Roundtable participants want to see this role evolve into TxDOT becoming less of a maintainer/builder of highway infrastructure and more of a manager/facilitator of Texas' freight transportation system.

Participants offered a number of examples of how TxDOT's role can change in the future to become more of a manager/facilitator of Texas' freight transportation system. For example, roundtable participants noted that environmental permitting is becoming very difficult, and regulatory requirements are becoming very burdensome. It is becoming very difficult to build freight infrastructure. The participants noted that TxDOT has relationships with public-sector agencies and private industry, and is in an ideal position to foster greater cooperation and understanding and to advance the implementation of freight infrastructure projects. TxDOT can

also help with the requirements of the National Environmental Policy Act for a rail project or facilitate discussions with the U.S. Army Corps of Engineers regarding permitting when a water body is involved in the development of a freight project. Participants suggested that TxDOT be a facilitator between the private sector and public sector by identifying the needs of freight stakeholders, being responsive, and being innovative. Overall, roundtable participants emphasized that TxDOT should facilitate relationships to support a consistent and reliable multimodal freight transportation system by 2055.

PILOT INNOVATIVE FREIGHT POLICIES/TECHNOLOGIES

Under this theme, a number of sub-themes/strategies emerged that describe the future role freight stakeholders are expecting of the state's transportation planning agency:

- Be an innovator.
- Pilot innovative transportation policies (e.g., incentivizing off-hour deliveries and barge transportation, and piloting oversize/overweight urban corridor projects).
- Pilot new technologies (e.g., truck-only lanes for truck platoons, and drones).

An Innovator

The Freight 2055 Roundtable discussion revealed that freight stakeholders in the state expect TxDOT to become more nimble, more responsive, and more innovative. There is a perception that TxDOT moves slowly and that the technology employed by the agency is outdated. It was recommended that TxDOT look to the Florida Department of Transportation (FDOT) as an example. FDOT is implementing a promising new initiative through its Office of Design, titled Invitation to Innovation. By employing outside-the-box thinking, the agency has developed many solutions that can be easily tailored to specific projects to make every dollar invested in transportation more efficient. The initiative resulted in a list of concepts, services, and products that may offer cost-effective solutions to the agency's needs and challenges (Florida Department of Transportation 2015). Many of the ideas listed have proven successful in other states and countries. It was suggested that some of these ideas may be aptly applied to Texas' freight transportation challenges and offer a starting point for Texas' own formation of an Invitation to Innovation program.

Although TxDOT has piloted a number of innovative initiatives in recent years (e.g., the My35 online tool and Project Tracker), there is the expectation that TxDOT will lead in 2055 as a freight innovator that can assist other transportation agencies in the area of freight planning and development of a freight transportation system that meets the needs of future businesses. Specifically, these needs include redundancy—such as alternative routes, which are important when accidents occur—and resiliency in the freight network.

There is also an expectation that TxDOT will address issues concerning the use of double trailers, oversize/overweight trucks, and first-mile and last-mile logistics over the next 40 years. Several participants remarked that TxDOT should allow heavier marine containers on its network because other states allow heavier containers and Texas ports need to remain competitive.

Innovative Transportation Policies

It was felt that TxDOT could support positive changes to the freight transportation system in the future by piloting innovative freight policies that can be implemented at the regional and local levels. TxDOT can assess the impacts and provide regional and local agencies with informed guidance.

Examples of innovative pilot freight policies that were offered include:

- Incentivizing the diversion of containers moved by truck to barges over short distances, such as from Beaumont to Houston.
- Implementing oversize/overweight urban corridors.
- Allowing high-occupancy vehicle lanes to be used by trucks.
- Separating passenger vehicle and truck traffic in urban corridors.
- Incentivizing nighttime truck travel and off-hour urban deliveries.

New Technologies

Roundtable participants felt that new technologies can help TxDOT be innovative and can make the freight transportation system safer and more efficient. Enhanced weigh-in-motion deployment was offered as an example of an innovative technology that can make the weighing of trucks more efficient. Several participants mentioned that truck-only lanes would make freight movement more efficient and would be particularly relevant if truck platooning is implemented.

TxDOT is already working with its university partners to research emerging transportation technologies that include Google's driverless car, jet packs, and hover cars (Batheja 2014). The next step would be to identify and pilot some of the technologies that will enhance Texas' freight transportation system.

SERVE AS A FREIGHT DATA CLEARINGHOUSE

The roundtable participants recommended that TxDOT be the data clearinghouse for freight activity data for the state. Specifically, freight stakeholders are expecting TxDOT to:

- Collect and maintain big data/mega-data to better plan for freight transportation and to address bottlenecks.
- Analyze freight trends and develop robust models.
- Develop mobile applications (e.g., text alerts involving trucks).

Big Data/Mega-data

TxDOT currently uses data and will continue to use data. Participants noted that data should inform everything TxDOT does so that the agency can develop a more efficient, safer, and reliable transportation system.

The roundtable participants recommended that TxDOT become the custodian (depository) and clearinghouse for big data/mega-data for freight activity (including rail and maritime transportation). The participants specifically recommended that the data sources include qualitative and quantitative data from freight stakeholders (including 3PLs) and the public at large. The data could then be used by the private sector and shared with the legislature to inform freight policies and develop robust freight models. Participants also mentioned that TxDOT should use big data/mega-data to better address congestion and bottlenecks in the future. One constraint to this recommendation is that the rail sector is typically more concerned about keeping data confidential. Private rail companies will have to be involved from the beginning to ensure the concept gets buy-in and the freight database is robust.

Freight Trends and Robust Models

International and specifically NAFTA trade is an important component of freight movements in Texas. The roundtable participants recommended that TxDOT analyze and track

import and export patterns, as well as stay abreast of Mexican investments in freight infrastructure to predict where—in terms of geographic location and mode—Texas may experience a change in NAFTA traffic. International trade and ports of entry should be an area of TxDOT focus for future study and proactive freight planning (specifically on the border). It was also recommended that TxDOT develop a dynamic predictive freight model for Texas to anticipate congestion and freight bottlenecks. To date, a lack of robust freight activity data has prevented the development of a robust freight model for the state. The situation could potentially be remedied if the agency becomes a custodian/clearinghouse for freight activity data.

Mobile Applications

Roundtable participants wanted TxDOT to invest in the development of mobile applications (i.e., apps) that, for example, alert drivers when accidents occur. Specifically, a freight app that provides information on weather, traffic, and accidents would overcome the limitations of the road signage currently used. Participants felt that the current road signage is neither sufficient nor reliable.

Participants thought that the My35 initiative was beneficial in informing the public about developments on the I-35 corridor. It keeps the public informed about projects and road conditions (e.g., accidents, closures, rest areas, and construction), and provides traffic camera views along 588 miles of the I-35 corridor. It was strongly recommended that the My35 concept be expanded and freight apps be developed to inform the public and stakeholders about conditions on the freight transportation system.

EDUCATE AND REACH OUT TO PUBLIC, LEGISLATORS, AND FREIGHT STAKEHOLDERS

Roundtable participants noted that communication with the public, legislators, and freight stakeholders is key to a more informed understanding of the importance of freight and the need to invest in all freight modes in the state. When the public is better informed, they will have an improved understanding of the freight transportation issues, the impacts on them, and what TxDOT can do to address these issues. Enhanced education will help the public and freight stakeholders understand their role and the role of TxDOT in the larger state transportation system.

Roundtable participants emphasized that TxDOT should invest in information and education campaigns on important freight issues (e.g., freight impacts imposed by bridge clearance heights) to educate the public and legislators. In general, the public does not understand the costs and issues associated with freight movement. Through better education, people can make more informed decisions, which can also support the goals of freight stakeholders. Roundtable participants stressed that information should be presented so that people understand how freight personally affects them. This can be done through a series of advertisements, newsletters, webpages or websites, and social media.

Roundtable participants were pleased with the January Transportation Forum and supported TxDOT's continued hosting of the forum. Project Tracker is an information tool that allows the public to obtain information about projects in the state or county, as well as projects funded with Proposition 12 and 14 bonds or through the Stimulus Program. Project Tracker provides extensive detail about each funded project, including the project description, funding estimate, bid date, and district/county of the area to be impacted. This is an invaluable tool that allows the public to participate and stay informed of TxDOT's plans to improve roadways. A similar tool or component of the tool that tracks freight projects could be significant in informing the public and freight stakeholders about planned freight initiatives.

CHAPTER 9:
CONCLUSIONS

This research study identified emerging factors and trends that could impact future business models and the associated impacts on Texas' freight system and transportation infrastructure. Through a detailed review of the literature and interviews with major Texas and U.S. businesses and major Mexico manufacturers, the study team discussed the identified global trade, sociodemographic, environmental, and technology trends that could impact Texas' businesses and trade with Mexico in the future.

The research team also hosted a one-day workshop, the Freight 2055 Roundtable, to review the identified factors and trends with a diverse group of freight stakeholders that represented both the private and public sectors. The workshop discussed the role of TxDOT in conducting proactive freight planning that will support the future growth of industry and ultimately of the Texas economy. Roundtable participants offered a number of suggestions and recommendations to frame the role of TxDOT in preparing the Texas freight transportation system for 2055.

This chapter highlights some of the salient findings of the research by chapter.

GLOBAL TRADE TRENDS

Chapter 2 reviews global trade trends and the factors that could impact global and Texas trade in the future. According to the U.S. Census Bureau, Mexico is Texas' top trading partner. It has the largest proportion of both imports from and exports to Texas. FHWA, however, predicts that the share of the value of goods traded with Mexico will decrease by 2040 as trade with Asia increases. Specifically, Texas trade with eastern Asia is projected to increase dramatically by 2040, with levels approaching those of Mexico.

Several trade factors and trends that could impact Texas trade in the future were documented, including TPP currently being negotiated, NEI, and the re-domestication of manufacturing, infrastructure bottlenecks, requirements for increased supply chain visibility, and changing customs regulations and the Single Window System. Specifically, the TPP FTA has the potential to change supply chains. Although it is unclear how Texas' NAFTA trade with Mexico will be impacted, it is relatively certain that the United States' trading relationship with Asia will

strengthen. This growth will translate into increased port traffic. Port capacity and port access will need to be evaluated in preparation for TPP.

TEXAS' SOCIODEMOGRAPHIC TRENDS

Chapter 3 reviews the sociodemographic changes predicted for Texas. The research showed that the population in Texas could increase from the estimated 26.4 million in 2013 to 32.1 million people (in the baseline case) or 55.2 million people (assuming the same levels of migration experienced between 2000 and 2010) by 2050. In Texas, the demographic trends point to a younger population (mostly Hispanic) that is growing faster than that of the United States as a whole. Texas' higher-than-average birthrates and the strong pace of net migration are the two main drivers behind these trends. Sociodemographic trends lie at the root of consumer demand and choices, and have a significant impact on the economic viability of any business model. The changes in demographic trends will impact the demand for transportation infrastructure and services in the future.

ENVIRONMENTAL TRENDS

Chapter 4 explores the physical changes to the environment that will impact transportation infrastructure and disrupt supply chain operations in the future if no action is taken to mitigate climate change. This chapter also outlines potential regulatory, industry, and consumer responses that could emerge in response to extreme weather events and to mitigate climate change.

The National Centers for Environmental Information reported that Texas experienced three extreme weather events in 2014 that resulted in more than $3 billion in damage. Furthermore, the Southern Plains Transportation Center noted that extreme summer temperatures, flash floods, and large numbers of freeze/thaw cycles, coupled with poor soils, have resulted in losses worth nearly $9 billion annually to manage transportation systems in Oklahoma and Texas.

Potential government responses explored include regulations, fuel economy standards, and carbon taxes. Industry responses include the use of renewable energies/alternative fuels and technologies, fuel cell trucks, improved vehicle utilization, investment in ICT to facilitate efficient scheduling, carbon labeling, reverse logistics, supply chain redundancy, and innovative

urban freight transportation practices. The chapter concludes that consumer demand for sustainable and low-carbon-footprint products will put pressure on the freight transportation industry to make changes and to have sustainable practices because consumers will make product selections considering product and shipping/transportation sustainability.

TECHNOLOGY TRENDS

Chapter 5 reviews current technologies (e.g., RFID and GPS) that shippers and freight carriers use to manage their operations, technologies accessible to consumers that are reshaping demand for goods and services (e.g., e-commerce), and emerging technologies that have the potential to transform the supply chain (e.g., 3D printing, truck platoons, and automated vehicles). The chapter notes that technology can be both a driver and enabler of transformation in logistics and a disrupter of logistics.

In this regard, there is little doubt that 3D printing is a transformational technology that can have a substantial impact on supply chains. For example, businesses will be able to provide replacement parts as required instead of trying to predict the need and manufacture the stock well in advance (as they do today). With 3D printers, for example, service parts engineers can download designs for spare parts and print them in a very short time. The supply of raw materials that are used to print items will need to be transported as opposed to the items—this will impact the logistics industry.

Similarly, big data and the analytics to uncover information can have a substantial impact on the logistics industry. Big data offers the potential for optimizing capacity utilization, reducing risk, improving customer experience, and creating new business models. The study team concluded that many companies have yet to leverage big data analytics to transform their supply chain operations. Many companies have access to large quantities of data but are unsure how to use it to drive their supply chains.

IMPORTANCE OF TRANSPORTATION IN BUSINESS LOCATION DECISIONS

Chapter 6 explores the importance of eight identified factors in site selection decisions and how Texas ranks on each of the identified factors. The study team found that the most important factors (i.e., tier 1 factors) that influence site selection are access to key markets, access to transportation infrastructure and multimodal transportation, skilled labor and

workforce, and suitable utilities and facilities. These factors are used to narrow the potential site lists to a few areas, regions, or cities. Once these factors are satisfied, the tier 2 factors that will determine the ultimate site decision include environmental costs, tax environment, financial incentives, and potential natural disaster or climatic events.

In general, Texas ranked neutral on the tier 1 factors, although there was some variation in the ranking depending on the type of industry/company that the site selector represented. On the tier 2 factors, Texas ranked favorably, in general. As Texas continues to compete with other states to attract industries and sectors to the state, a greater emphasis is potentially needed to improve Texas' ranking on the tier 1 factors, which include access to transportation.

CHANGING BUSINESS MODELS

Chapter 7 discusses the changing business models that are emerging based on the study team's review of the literature and the information that was shared with the study team during the interviews. The business models explored are the JIT business model; outsourcing, nearsourcing, and insourcing models; omni-channel commerce; green supply chains; and the collaborate-to-compete business model.

The collaborate-to-compete business model is worth highlighting. Collaborate to compete is an emerging business model that recognizes the insufficiency of individual efforts to tackle complex problems. As economies become more complex and as companies are increasingly being held accountable for their business practices, companies need a wide range of skills to succeed. Therefore, the realization that an individual company cannot have all the knowledge, personnel, systems, suppliers, customers, and relationships it needs to succeed has resulted in collaboration among competitors. Examples of collaboration among competitors were identified in the literature and documented in this chapter.

FREIGHT 2055 FRAMEWORK

Chapter 8 discusses the four themes that provide a framework for the role of TxDOT in preparing for an efficient, reliable, and safe freight transportation system in 2055 that supports the growth of industry and ultimately the Texas economy. First, the Freight 2055 Roundtable discussion revealed that freight stakeholders anticipate TxDOT to be a facilitator/manager of Texas' freight transportation system by 2055. The stakeholders expect TxDOT to evolve into a

multimodal transportation agency that advocates for all modes of freight transportation (not only highways), provides funding for all freight modes, focuses on connectivity projects (not only congestion), and facilitates among different agencies and the public and private sectors to advance freight projects.

Second, freight stakeholders expect TxDOT to become more nimble, more responsive, and more innovative. There is the expectation that TxDOT will lead in 2055 as a freight innovator that can assist other transportation agencies in the area of freight planning and development of a freight transportation system that meets the needs of future businesses. Specifically, it was recommended that TxDOT pilot innovative transportation policies (e.g., incentivizing off-hour deliveries and barge transportation, and piloting oversize/overweight urban corridor projects) and invest in pilots of new technologies (e.g., truck-only lanes for truck platoons, and drones).

Third, freight stakeholders recommended that TxDOT be the data clearinghouse for freight activity data for the state. Specifically, freight stakeholders expect TxDOT to collect and maintain big data/mega-data to better plan for freight transportation and to address bottlenecks, analyze freight trends and develop robust models, and develop mobile applications.

Finally, freight roundtable participants noted that communication with the public, legislators, and freight stakeholders is key to a more informed understanding of the importance of freight and the need to invest in all freight modes in the state. The freight stakeholders emphasized that TxDOT should invest in information and education campaigns on important freight issues to educate the public and legislators. Participants felt it is the role of the state transportation planning agency to educate and inform the public on freight issues and the need to invest in all modes of freight transportation.

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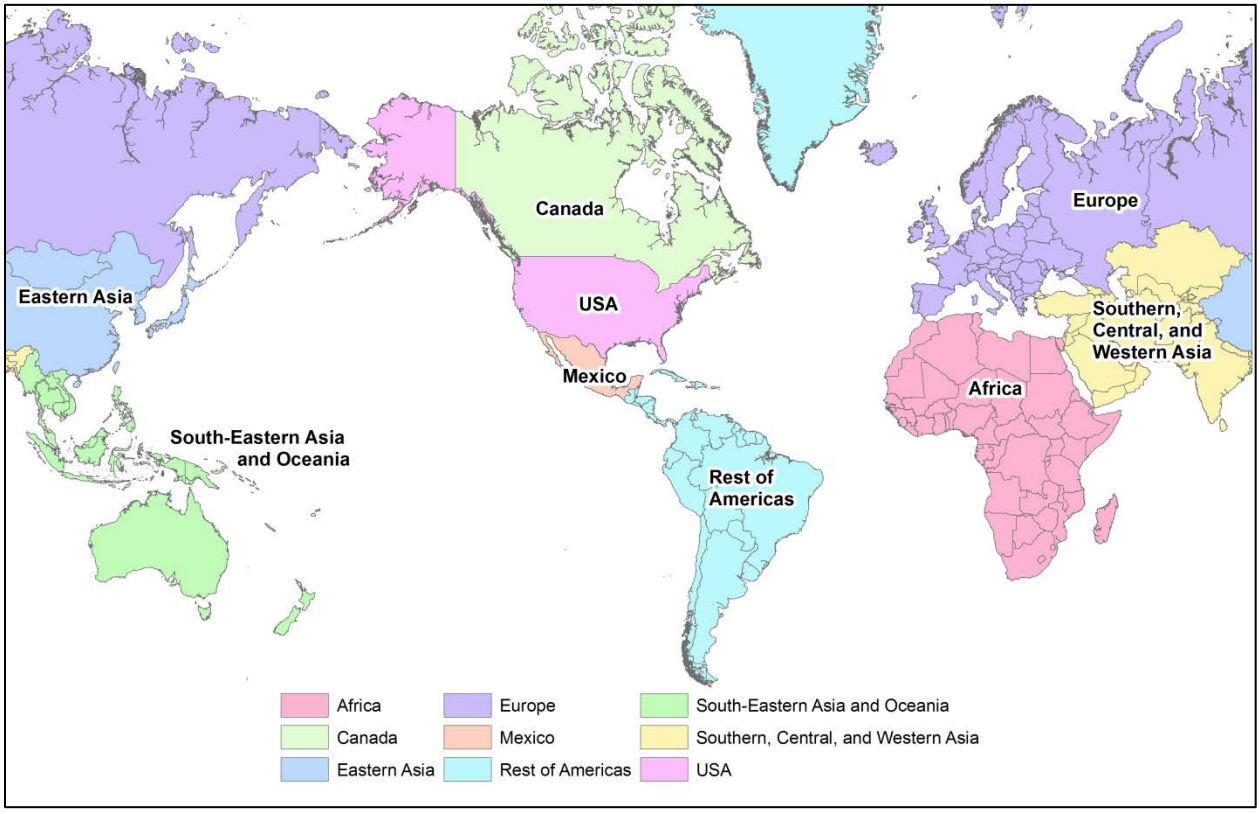
APPENDIX A:
OVERVIEW OF U.S. TRADE

The Federal Highway Administration (FHWA) Freight Analysis Framework (FAF) database characterizes freight movements for past and current years but also projects out to 2040. This includes the estimated trade value of shipments to and from the United States and from foreign countries. The FAF database represents the foreign countries within eight total international regions, as shown Figure A-1.



Source: Federal Highway Administration 2012.

Figure A-1. FHWA FAF World Regions.

For the United States in 2012, the top world regional trade partner was eastern Asia, followed by Europe, Canada, and Mexico (see Table A-1). Eastern Asia, which includes China, accounted for more than 28 percent of the trade, by value, in 2012, with that share expected to grow in 2040 to more than 32 percent. The rest of the Americas, which includes Brazil, is the only other world region that is projected to gain share over the analysis period. In examining the rank of the regions, the only projected change is the rest of the Americas region overtaking Mexico as a result of its gain in the share of trade with the United States.

Table A-1. FHWA FAF World Region Total Trade Values with the United States.

World Region	Percent Value		
	1997	2012	2040
Eastern Asia	25.5%	28.5%	32.4%
Europe	20.8%	20.7%	19.7%
Canada	20.9%	16.3%	15.4%
Mexico	10.3%	12.9%	10.2%
Rest of the Americas	7.4%	9.4%	11.9%
Southern, central, and western Asia	4.1%	5.6%	4.3%
Southeastern Asia and Oceania	9.3%	4.0%	4.2%
Africa	1.8%	2.6%	1.8%

Source: Federal Highway Administration 2012.

The top world region for the share of U.S. export trade, in terms of value, in 2012 was Europe, with a slight edge over eastern Asia (see Table A-2). As with the overall trade share, eastern Asia and the rest of the Americas are expected to gain in the share of trade with the United States for both exports and imports. The southeastern Asia and Oceania region is also expected to have an increase in share for both exports and imports. Canada is expected to have a slight increase in share for the value of shipments to the United States.

Table A-2. FHWA FAF World Region Export and Import Share of Trade with the United States.

World Regions	Export Percent Value			Import Percent Value		
	1997	2012	2040	1997	2012	2040
Eastern Asia	20.6%	21.2%	26.1%	29.3%	33.5%	37.2%
Europe	22.4%	21.3%	20.9%	19.5%	20.3%	18.9%
Canada	22.5%	18.9%	16.4%	19.6%	14.5%	14.7%
Mexico	10.6%	13.9%	10.2%	10.0%	12.3%	10.3%
Rest of the Americas	9.0%	11.8%	14.7%	6.0%	7.7%	9.8%
Southern, central, and western Asia	4.1%	6.2%	5.3%	4.2%	5.2%	3.6%
Southeastern Asia and Oceania	9.2%	4.6%	4.8%	9.3%	3.6%	3.7%
Africa	1.5%	2.1%	1.7%	2.0%	2.9%	1.9%

Source: Federal Highway Administration 2012.

Focusing on the trade between the United States and individual countries, the International Monetary Fund indicates that Canada ranks first, with more than $658 billion in trade with the United States in 2014, representing 16.6 percent of the total share (see Table A-3). This is followed by China with 14.9 percent of the trade share and Mexico with 13.5 percent. The balance of trade between the United States and Canada and between the United States and Mexico is generally equal in both directions, whereas trade between the United States and China

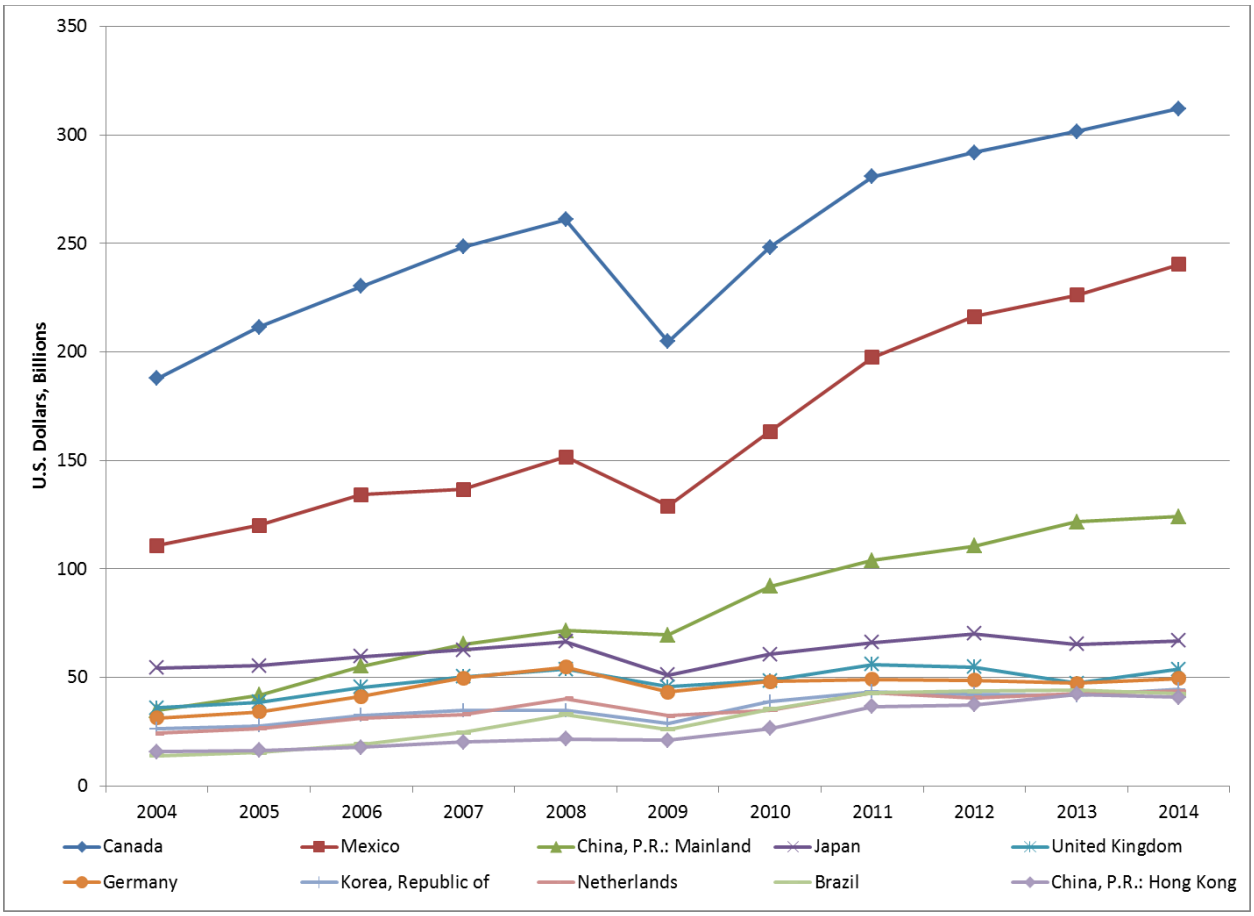
is largely imports into the United States. The first major trade partner that experiences more imports from the United States than exports to the United States is Brazil, with 58 percent of the trade with the United States being imported into Brazil.

Table A-3. Top 25 U.S. Trade Partners in 2014 (Millions of U.S. Dollars).

Country	Rank	Export	Import	2014 Total	Percent of Total
Canada	1	312,125	346,063	658,188	16.6%
China: Mainland	2	124,024	466,656	590,680	14.9%
Mexico	3	240,326	294,157	534,484	13.5%
Japan	4	66,964	133,939	200,903	5.1%
Germany	5	49,443	123,181	172,624	4.3%
Republic of Korea	6	44,544	69,606	114,150	2.9%
United Kingdom	7	53,865	54,049	107,914	2.7%
France	8	32,354	47,149	79,503	2.0%
Brazil	9	42,418	30,337	72,755	1.8%
Taiwan, Province of China	10	26,836	40,572	67,407	1.7%
India	11	21,628	45,228	66,856	1.7%
Saudi Arabia	12	18,679	47,038	65,716	1.7%
Netherlands	13	43,669	20,807	64,476	1.6%
Italy	14	16,996	42,105	59,101	1.5%
Belgium	15	34,824	20,905	55,729	1.4%
Switzerland	16	22,660	31,480	54,140	1.4%
Singapore	17	30,532	16,463	46,995	1.2%
China: Hong Kong	18	40,877	5,794	46,671	1.2%
Malaysia	19	13,136	30,448	43,584	1.1%
Ireland	20	7,773	33,982	41,756	1.1%
Venezuela	21	11,339	30,219	41,558	1.0%
Thailand	22	11,791	27,121	38,913	1.0%
Colombia	23	20,317	18,234	38,551	1.0%
Israel	24	15,074	23,051	38,124	1.0%
Australia	25	26,669	10,670	37,339	0.9%
Rest of the World		294,558	335,932	630,489	15.9%
Total		1,623,421	2,345,186	3,968,606	100%

Source: International Monetary Fund 2015.

The International Monetary Fund provides this export and import trade data between the United States and other countries from 2004 to the present. Figure A-2 displays the annual export levels for the top 10 U.S. trade partners. For U.S. exports, Canada and Mexico are the most significant trade partners, with China third. As shown in Figure A-2, trade levels for these three countries had significant growth rates over that time period, with China experiencing 257 percent growth. The remaining top 10 countries experienced more modest growth from the 2004 levels, with the 2014 U.S. export levels generally at or slightly above the pre-2009 levels.



Source: International Monetary Fund 2015.

Figure A-2. Top 10 U.S. Trade Export Partners.

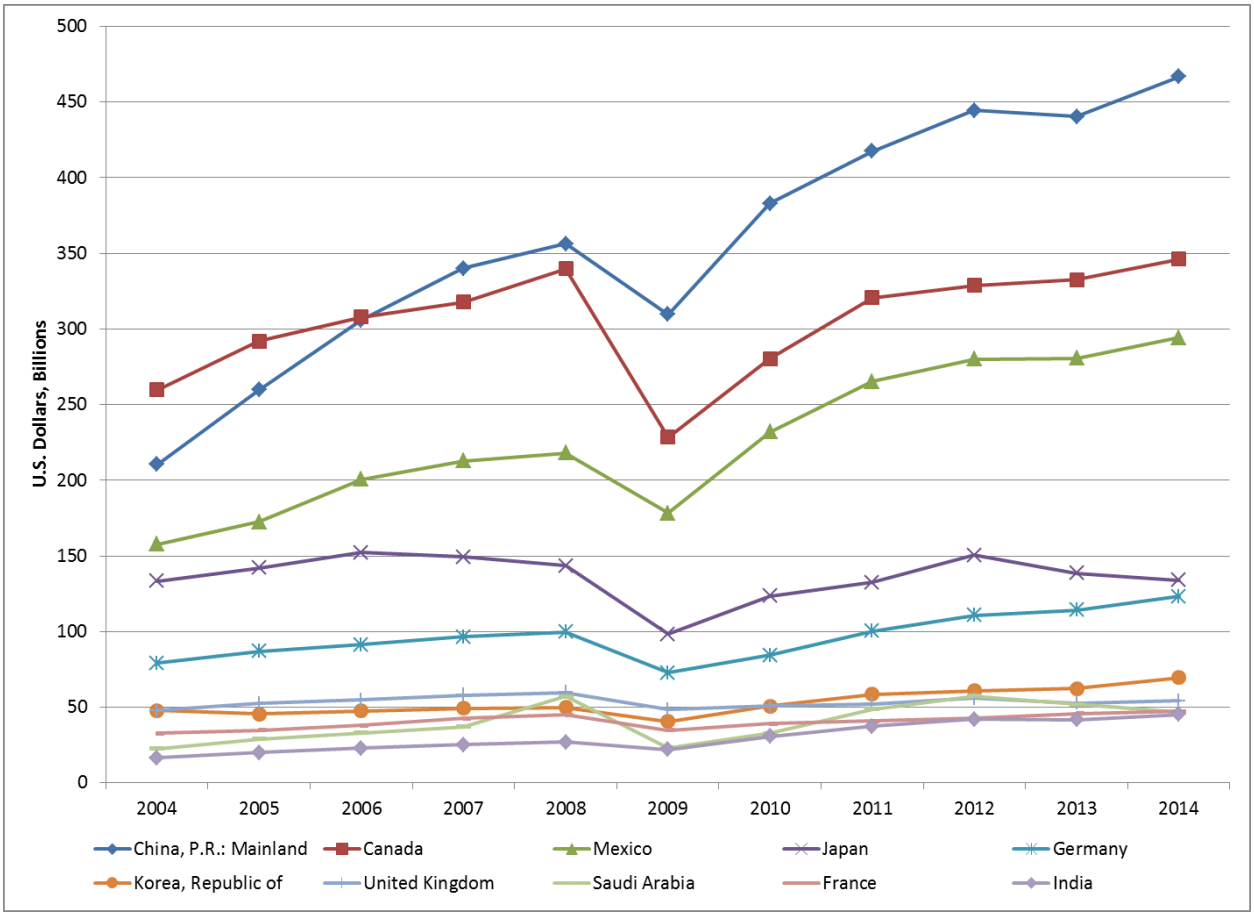
Table A-4 shows the percent growth for the top 10 export partners. In addition to China, Brazil also experienced more than 200 percent growth (206 percent) between 2004 and 2014.

Table A-4. Top 10 U.S. Trade Export Partner Growth in 2004–2014.

Rank	Trade Export Partner	Percent Growth, 2004–2014
1	Canada	66%
2	Mexico	117%
3	China: Mainland	257%
4	Japan	23%
5	United Kingdom	50%
6	Germany	58%
7	Republic of Korea	69%
8	Netherlands	80%
9	Brazil	206%
10	China: Hong Kong	159%

Source: International Monetary Fund 2015.

The top U.S. trade import partners are China, Canada, and Mexico, as shown in Figure A-3. China overtook Canada for the top importer spot beginning in 2007 and has grown by 122 percent since 2004 (see Table A-5). Other countries experiencing tremendous growth in exports to the United States from their 2004 levels include Saudi Arabia (109 percent) and India (175 percent). Traditional import partners Japan and the United Kingdom only grew over that period, less than 1 percent and 13 percent, respectively.



Source: International Monetary Fund 2015.

Figure A-3. Top 10 U.S. Trade Import Partners.

Table A-5. Top 10 U.S. Trade Import Partner Growth in 2004–2014.

Rank	Trade Import Partner	Percent Growth, 2004–2014
1	China: Mainland	122%
2	Canada	33%
3	Mexico	86%
4	Japan	0%
5	Germany	56%
6	Republic of Korea	46%
7	United Kingdom	13%
8	France	45%
9	Saudi Arabia	109%
10	India	175%

Source: International Monetary Fund 2015.

Many of the countries that have experienced tremendous growth in trade levels with the United States are also ones that have experienced tremendous growth in their country's gross domestic product (GDP). Table A-6 contains the top 20 leading economies by GDP and their percent share of the global GDP. The United States remains the leading economy, with a projected GDP representing more than 23 percent of the global economy in 2020. China accounted for only 2.8 percent of the global GDP in 1980 and is projected to account for more than 16 percent of the global GDP in 2020. This represents a 5,128 percent growth in GDP between 1980 and the projected levels in 2020. Other top gainers by percentage include India (1,906 percent), Brazil (1,447 percent), and the Republic of Korea (2,996 percent).

Table A-6. Top 20 Leading Economies by Gross Domestic Product in 1980–2020 (Projected).

Country	GDP, Billions of Current U.S. Dollars					Share of Global GDP		Growth
	1980	1990	2000	2010	2020	1980	2020	
United States	2,862	5,980	10,285	14,964	22,489	25.7%	23.1%	686%
China	309	404	1,193	5,950	16,157	2.8%	16.6%	5,128%
Japan	1,087	3,104	4,731	5,495	4,933	9.8%	5.1%	354%
Germany	850	1,591	1,953	3,418	4,105	7.6%	4.2%	383%
United Kingdom	566	1,099	1,552	2,409	3,731	5.1%	3.8%	560%
India	181	327	477	1,708	3,640	1.6%	3.7%	1,906%
France	704	1,279	1,372	2,652	3,013	6.3%	3.1%	328%
Brazil	152	475	657	2,209	2,354	1.4%	2.4%	1,447%
Italy	470	1,140	1,146	2,131	2,173	4.2%	2.2%	362%
Russia	N/A	N/A	260	1,525	2,081	N/A	2.1%	N/A
Canada	274	595	739	1,614	2,044	2.5%	2.1%	645%
Republic of Korea	65	279	562	1,094	2,012	0.6%	2.1%	2,996%
Mexico	235	298	684	1,051	1,653	2.1%	1.7%	604%
Australia	163	323	399	1,248	1,491	1.5%	1.5%	816%
Spain	230	534	597	1,434	1,487	2.1%	1.5%	546%
Indonesia	104	137	179	755	1,307	0.9%	1.3%	1,153%
Turkey	94	202	267	732	1,012	0.8%	1.0%	973%
Netherlands	189	313	415	838	911	1.7%	0.9%	382%
Saudi Arabia	164	117	190	527	902	1.5%	0.9%	449%
Taiwan Province of China	42	167	331	446	776	0.4%	0.8%	1,734%

Source: International Monetary Fund 2015.

APPENDIX B:
WORLD POPULATION AND U.S. DEMOGRAPHIC TRENDS

INCREASING POPULATION

Demographic factors, mainly the changing locations and age structures of populations, will be the key drivers of the next economic cycle. According to the *2012 Revision of the United Nations Population Estimates*, the 7.2 billion world population of 2013 is projected to increase by nearly 1.0 billion people within the next 12 years, reaching 8.1 billion in 2025 and further increasing to 9.6 billion in 2050 (United Nations 2013). Seven-eighths of the world's population is expected to live in emerging economies by 2050 (World Bank Group 2010). The population in developing countries is projected to rise from 5.9 billion in 2013 to 8.2 billion in 2050, and will mainly be distributed among the population aged 15 to 59 (1.6 billion) and 60 or over (1.99 billion); the number of children under age 15 in developing countries will barely increase (World Bank Group 2010).

In contrast, the population of the more developed regions is expected to change minimally, increasing from 1.25 billion in 2013 to 1.28 billion in 2050. The population in developed nations would decline if it were not for the net increase due to migration from developing to developed countries. This migration is expected to average about 2.4 million persons annually from 2013 to 2050. At the country level, high-fertility countries are expected to be the leaders in population growth between 2013 and 2050, mainly Africa and countries with large populations such as India, Indonesia, Pakistan, and the United States (World Bank Group 2010). The most populous nations will become key market destinations for most supply chains. This will require the development of new supply chain strategies for multinational corporations (Flint 2004).

AGING POPULATION

In the United States, demographic trends are moving the Baby Boomer generation toward an older population living in smaller households. However, according to data from the U.S. Census, the growth rate has generally been slowing since 1950 but still remains positive (Mackun and Wilson 2011). From 1990 to 2010, the population grew 1.08 percent per year due to birth rates, death rates, and immigration trends. Immigration trends are the most volatile, with

positive growth rates of more than 50 percent per year in some decades (e.g., 1990–1999) and negatively in others (e.g., 2000–2010). The U.S. fertility rate has been between 1.5 and 2.1 births per woman since the early 1970s, barely meeting the replacement rate at which the total population will remain constant (Haub 2009).

Increase in life expectancy at birth is resulting in more people living to an older age. Life expectancies have increased from about 72 years in 1975 to nearly 79 in 2010 (Murphy et al. 2013). The United States is getting older as a country, as reflected in an increasing share of persons 65 and older and an increasing median age in the population (Shrestha and Heisler 2011).

SUBURBAN LIFESTYLES

According to a Census 2000 special report, about half of Americans lived in suburban areas, one-third in central cities, and one-sixth in rural areas (Hobbs and Stoops 2002). Furthermore, in the last decades, most of the metropolitan growth came from suburbs rather than central cities. This trend is not expected to change. Also, according to the *2012 Vehicle Technologies Market Report*, in 1970, almost half of households had one vehicle, around 35 percent had more than one vehicle, and 17 percent had no vehicle. In 2010, households with one vehicle declined to 34 percent, while the share of households with two or more vehicles rose to 57 percent (Davis et al. 2012).

DEMAND FOR TRAVEL AND FREIGHT MOVEMENT

Although the U.S. growth rate of 0.7 percent is the lowest since the 1930s, according to the U.S. Census Bureau, an ever-larger population will increase congestion in high-growth areas and increase demand for travel and freight movement. By 2025, 20 percent of all drivers will be 65 or older. The demand for paratransit and emergency medical services tends to be higher for older road users. More elderly households are expected in rural areas, which can add to the challenge of providing needed services. Also by 2050, 50 percent of all households are expected to be living in single households. In Texas, the trend points more toward multi-generation households and family mix. This extends beyond the typically married couple with children. According to all these trends—combined with the income and spending data analyzed for the six

major metropolitan regions in Texas—more freight demand can be expected in regions where more consumption is expected to take place.

APPENDIX C:
INTERVIEW RESULTS

This appendix provides information about:

- The development of a sampling frame of Fortune 500 companies and major maquilas in Nuevo Laredo and Juárez.
- Interviews of a statistical sample of executive-level managers at Fortune 500 companies within Texas and out of state, and Mexican maquilas in Nuevo Laredo and Juárez to get an understanding of the influencing factors, drivers, and dynamics behind the anticipated changes in their business models and operational strategies, as well as the assumptions, requirements, and impacts foreseen on the freight transportation system 40+ years in the future.
- Analysis of the information obtained during the interviews and development of matrices showing the influencing factors, drivers, and dynamics behind the anticipated changes in business models and operational strategies, as well as the assumptions, requirements, and impacts foreseen on the future freight transportation system.

METHODOLOGY

The bills that govern spending for surface transportation have noted that an understanding of the freight transportation sector's needs for the system is a critical component of the transportation planning effort. However, there currently is an inadequate understanding of how the private sector approaches freight movement decisions, as well as what factors are included in their business models and how the factors are used.

To garner this information, the University of Texas at Austin's Center for Transportation Research (CTR) in conjunction with the Texas A&M Transportation Institute (TTI) developed a survey instrument to be used to interview individuals from Fortune 500 companies headquartered within Texas, Fortune 500 companies not headquartered within Texas, and Mexican maquilas. This survey instrument includes four questions:

1. What factors influence your current business model or are included in your current business model?
    a. Demographic factors (aging population, suburban lifestyles, etc.).

   b. Global trade patterns (emerging markets, global security concerns, volatile commodity prices, etc.).
   c. Environmental regulations (international climate regulations, sustainability, extreme weather, etc.).
   d. Technology (personal fabrication, big data, online retailing, etc.).
2. Briefly, how do these factors impact your model?
3. Based on your company's expectations for freight transportation systems, how do the above factors impact:
   a. Changes in sourcing patterns (changes in the origins of freight movements)?
   b. Changes in freight destinations (locations of final demand)?
   c. Changes in routing patterns and modes used?
   d. Changes in freight volumes?
   e. Changes in value (characteristics of products)?
4. Looking into the future, what changes do you anticipate needing of the freight transportation system within the next 40 years?

FORTUNE 500 COMPANIES

In order to determine which corporations to include within the study, TTI examined the Fortune 500 list to determine which firms were headquartered within Texas. After the identification of the 52 Texas companies, TTI categorized these by economic sector to establish a sampling frame. For each of these firms, researchers at CTR and TTI identified key contacts. Of these 52 companies, only three agreed to participate in the survey. This limited response rate created a need to expand the outreach, and with the assistance of Dr. Terry Pohlen of the University of North Texas, researchers were able to contact 28 corporations headquartered within Texas and out of state, leading to 11 additional participants, most of which were companies with a significant presence in Texas. Due to the nature of the information given in these interviews, no company or interviewee names are included in this appendix.

The results of these interviews will be discussed in the next subsections based on the following market segments:

- Food and beverage.
- Oil and gas.

- Manufacturing.
- Retail.
- Transportation.

Food and Beverage

Within the food and beverage market segment, the factors that influenced/were included in the business model included the demographic factors of population growth and consumer trends. These factors were used to improve production efficiencies. Global trade patterns and volatile commodity prices were noted as impacting sourcing of materials. For the environmental regulations factors, sustainability and alternative fuels were mentioned as well as international climate regulations and weather impacts. The use of computerized routing plans was mentioned as being incorporated into the business model for the technology factors. In conjunction with the use of demographic factor for production efficiencies, the use of computerized routing was changing the production locations from regionally based to nationally based. Three-dimensional printing was noted as being considered, and its potential use would be for parts.

Sourcing patterns and freight destinations were noted as not changing unless there were capacity limitations, large differences in modal pricing, weather issues, or legislative restrictions. Modal changes were noted only due to weather limiting intermodal loads but only for extreme weather events. Modal changes impacted value changes, which were also impacted by commodity prices and global trade patterns in a negative manor. Freight volumes were impacted negatively due to weather events as well as legislative and regulatory actions.

For the future needs of the freight system, in the nearer term, the items mentioned included a North American Free Trade Agreement (NAFTA) corridor, increased rail capacity, more access to alternative fueling locations, and more intermodality. Weight allowances and trailer lengths in Texas were noted as being behind compared to surrounding states. Respondents noted that a tractor with two trailers provides the greatest gains for the industry. Drone and autonomous vehicle technologies were also mentioned, along with high-speed freight rail, as longer-range items.

Oil and Gas

The oil and gas segment included the aging workforce and suburban lifestyle as relevant demographic factors. The global trade pattern grouping mentioned security and theft as well as

growing domestic operations (emerging markets). Safety and environmental compliance were noted as a factor in the environmental regulations grouping. The technology mentioned included driver safety technology, smart trucks, and cleaner, more efficient and hybrid engines. The oil and gas industry outsources its transportation of freight and equipment. Freight volumes were noted to change seasonally, and the overall trend is less demand from developed countries and larger demands from developing countries.

Themes from the future needs question included the need for more efficient and safer vehicles, as well as hybrid, diesel, and electric vehicles in the near future. Further into the future, new materials for truck construction that will be lighter weight and stronger could be possible and would have impacts on bridge and pavement designs.

Manufacturing

The manufacturing segment had a broad range of incorporated factors that were included within its business models. For the demographic category, two of the interviewees included all factors, while the other three did not include any. Three of the interviewees included the global trade pattern factors, with international emerging markets and global security concerns being noted. Four companies included the following environmental regulations within their business model: governmental regulations, hazardous goods regulations, sustainability, and extreme weather events. Two of the companies noted the limited availability of refrigerated truck carriers. All of the interviewees mentioned technology factors as influencing their business models. These factors included online retailing, computer-based route modeling systems, and just-in-time delivery. Companies also watched for mergers between technology companies and made decisions to invest in, partner with, or acquire emerging technologies and/or technology companies. All of the previously mentioned business model factors were noted as being used to leverage the transportation system to minimize waste (i.e., dwell times), aid corporate growth and competitive advantages, and deliver value to the customers.

Sourcing patterns were noted as being reviewed continuously with domestic and international vendors in an effort to minimize the distance between distribution centers and the source materials/items. Sustainability was noted as an important factor for sourcing, and there was a preference to use more localized products when possible. One survey participant indicated that facilities were relocated to address the needs of employees, including access to mass transit,

airports, and higher education. Changes in freight destinations were product based, with one interviewee noting that products go where there is demand, which is "not always the best fit for transportation." This was true for domestic and international destinations, with international destinations showing growth. With respect to modal changes, the main mode was trucking, with some applications of intermodal deliveries and limited air and rail usage noted. International demands may increase air freight and other expedited modes. There will be increased movements in and out of ports, specifically the Port of Houston, to meet the anticipated demand. New routing patterns and modal usage for new products are being established based on the demand. Changes in volumes were noted as seasonally more volatile in spring for one interviewed company, while another mentioned that it was seeing an increase in product demand and that full production was not expected until 2020. Another company mentioned that rather than volume, dimensional weight was a fact for the company and created a need for more analysis and adjustments from the freight system. Two of the companies noted that products were becoming more expensive, and the cost of moving freight both domestically and internationally was increasing.

Themes from the future needs question included concerns about the aging driver workforce and potential labor shortages within the trucking community. Similarly, the limited number of qualified drivers for the movement of dangerous goods was noted. The end points for delivery could change in the future, with more people having the ability to work from home. With respect to modal needs, it was anticipated that ocean freight would increase. Two corporations noted the need for dedicated roadways or lanes for freight as well as for oversized/overweight vehicles along highways and to and from airports. The need for more intermodal features, increased refrigerated rail, expansion of the rail system, and high-speed rail services were also noted. Two companies noted connected and autonomous vehicles as needing to be investigated further by TxDOT, with a note that there were security concerns based on the type of freight potentially moved via these vehicles. Finally, one company noted that it had plans to implement point-of-use manufacturing strategies (i.e., 3D printing) for required commodities.

Retail

All factors were noted as being included within the business models for the retail companies interviewed. Demographic factors are used to understand consumer needs and

preferences to determine the products sold and how the products ultimately get to the consumer (i.e., e-commerce versus traditional brick-and-mortar stores). Global trade was noted as having impacts on the sourcing locations of products and emerging markets, and reviews are done to monitor for risks (e.g., port issues domestic and abroad). Sustainability, environmental regulations, and climate changes were noted as impacting sourcing and supply chain costs. Both of the retail companies noted the use of data for better serving customers and improving supply chains.

Changes in sourcing patterns were noted as being impacted by costs, geopolitical climates, sustainability concerns, human and worker rights, and complexities in supply chains. Destinations were influenced by emerging markets that are dominated by a growing middle class. Geopolitical climates were noted for their limitation of product dentations. With respect to routing and modal patterns, the interviewees noted that there were adjustments made away from rail disruptions and port issues (e.g., West Coast port strikes). E-commerce has the potential to change routing patterns and modes used, with traditional stores potentially changing in function to just having display models and directly shipping items to consumers (i.e., residential deliveries). Shrinking lead times could encourage smart global shipments in the future. Volumes are driven by demographic factors, and generational differences (e.g., Baby Boomers versus Millennials) were a driving force for volumes. The same was noted for value changes. Products are based upon the needs of customers, sourcing decisions, technology, and costs.

Future system need themes included the continued use of e-commerce, which has the potential to change the function of the brick-and-mortar stores as noted previously. The need to maintain and upgrade existing infrastructure, ensure adequate intermodal connection to business parks, and support more efficient freight movements through new vehicle combinations were also mentioned. Automation-supported highways were another theme from the retail sector. Finally, the need for a long-term sustainable funding source was noted.

Transportation

The final market segment is transportation, which includes logistics and modally based companies. Demographic factors included aging populations and their need for a system that can handle their current and future consumption of medical and perishable deliveries. Sourcing concerns, commodity volatility, and emerging markets were factors that influenced global trade

patterns for border freight movements of perishables and retail goods. Security is another area of concern for the transportation segment, and there is a need to resolve differentiation in security standards between countries from a logistics perspective. On the environmental spectrum, sustainability is now expected to be incorporated by the shipping industry, and extreme weather events were being considered in a proactive and reactive manor. Finally, e-commerce has changed the way freight moves, and the direct-to-consumer model has changed delivery locations, which can be at nontraditional places (e.g., 7-11 stores). Another factor was the shrinking sizes of items that are being shipped due to advances in technologies. Technology was needed to address costs and leads to competitive advantages.

Nearshoring was noted for changing the sourcing patterns for freight coming from southeast Asia and from Mexico. Latin America was also mentioned as an area seeing development, and thus more freight will be coming out of and into this area. The border and ports are seeing an increase in freight as well, and this is likely to continue to increase with the Panama Canal expansion. Delivery speed was another factor mentioned that was changing sourcing patterns. Export destinations were noted as growing for the Asian consumer because their demands for American products are increasing. Routing and mode changes are impacted by new flights at new airports, region-to-region and point-to-point hauling, port issues (e.g., the West Coast port strike), and multimodal opportunities becoming available. Changes in freight volumes were noted as increased flight opportunities for air freight and increased border freight. Air freight was often used for higher-valued products (e.g., high tech and pharmaceuticals), and little to no change was noted with the exception of the impacts from the West Coast port strike situation.

Trends that were noted during the interview process for the future freight system needs included the need for increased freight space at airports and a more efficient air traffic control system for air freight. For surface transportation, the need to build out the freight infrastructure at the border to keep up with border growth was noted, as well as a need for more rail and improved rail hub facilities to accommodate the larger ships coming into ports. Funding and security concerns were brought up within this market segment as well. Connected and autonomous vehicles and their potential to be an impactful technology for freight were mentioned, noting there were concerns about how the technologies would play out within the United States. Finally, global positioning systems were mentioned as an area that will continue to

have developments and that has become more cost effective for the freight industry's tracking of goods.

MEXICAN MAQUILAS

As documented by the latest Texas International Trade Corridor Plan, Texas trade with Mexico keeps increasing at an accelerated pace (Bujanda and Villa 2012). The number of Mexican companies that depend on an efficient freight transportation system in Texas (e.g., roads, border crossings, and railroads) to conduct day-to-day business operations continues to increase. This subsection aims to identify potential assumptions, requirements, and impacts on the future freight transportation system as a consequence of increasing trade with Mexican companies. In order to get an understanding of the influencing factors, the key drivers, and the dynamics behind the anticipated changes in business models and operational strategies, this subsection presents the response to confidential in-person and telephone interviews of a sample of more than 15 Fortune 500 and maquila executives in Mexico spanning across six main industry sectors:

- Food and beverages.
- Automotive.
- Steel and mining.
- Construction materials.
- Transportation.
- Manufacturing.

Food and Beverages

A general finding among executives interviewed in the food and beverage industry sector is that, in the long run, the supermarket experience will gradually disappear in favor of more orders online. The distribution model will be replaced by a new one using very large distribution centers, and last-mile delivery will have to be done on much smaller trucks, vans, or even drones. The future freight transportation system should be prepared to consider customers' orders and their location and be in sync with last-mile delivery in order to avoid congestion in the streets. Executives interviewed in this industry sector recognize that the adoption of technological innovations in the transportation and shipping sectors has taken place at a very slow pace in the

last decades. Currently, information flows—regarding the condition of the freight transportation system to allow planning better routes—and shipping times are not integrated into the overall supply chain. For example, shipments usually get delayed because of traffic congestion, construction zones, and inclement weather, and there is no way for supply chain managers to anticipate such delays. Similarly, delays at border crossings have a direct implication on the final price of a product, ultimately affecting the consumer. In the long run, most executives view the Internet as a viable tool to develop solutions for truckers and supply chain managers to anticipate and mitigate shipment delays and plan production accordingly. However, most executives recognized that very few companies have access to their entire supply chain in the cloud. Additionally, as the adoption of a green supply chain continues, the transportation infrastructure needs to be prepared to welcome green fuels and renewable energy.

Automotive

According to executives interviewed in the automotive industry in Mexico, the ideal vision for the future is to implement direct pull orders, in real time, from the point of sale, all the way up through each segment of the supply chain. Suppliers will need to have inventories located closer to the manufacturing base so that production plants can receive smaller batches of raw materials on a more frequent basis, rather than larger shipments on a more infrequent basis, as it is currently done. However, maquila executives recognize that such a business model represents an inherent conflict with how shippers currently operate. Shippers benefit more from economies of scale. Ultimately, the goals are to maximize flexibility and minimize inventories throughout the chain, and any plant will work hard to continue improving such goals. Regarding technological changes, the most important thing is having an interface connecting all systems and stakeholders of the chain worldwide, including the transportation segment.

Regarding demographic changes, this generation is the first with access to immediate consumption online, and this is creating unique challenges in the administration of supply chains and natural resources. Maquilas currently do not sell directly to final consumers, but they have to anticipate and react to changing demographic trends to modify their production, inventory, and transportation requirements. Automotive companies have to adapt to the demand characteristics of new market generations. For example, in response to sustainable measures increasingly promoted by cities to decrease the use of and reliance on the use of the automobile, automotive

companies are investing in research, development, and commercialization of green and ecofriendly technologies. Internally, people typically join the automotive companies as interns, stay as part of the companies' workforce, move throughout their subsidiaries several times during their careers, and retire from the companies after 40 years. Mobility of young labor has been an efficient strategy for exploiting cross-pollination of skills and talent; it has helped to complement the expertise of older generations, fostering innovation.

The business model of Mexican companies in the automotive industry is suffering some dramatic changes. In transportation, shippers seek to maximize the volume per shipment to generate economies of scale and optimize transportation costs. However, efficient manufacturing systems are more cost-efficient handling much smaller volumes than what is typically handled by the carriers. Eventually, the application of smart technologies to monitor consumption habits will have a profound impact on the administration of supply chains. Demand will be monitored, and production will be scheduled in real time. Hence, the transportation and logistics industries will have to become more efficient in handling much smaller volumes on a more frequent basis. Moreover, the transportation infrastructure will need to be prepared to consider customers' orders and their location and be in sync with last-mile deliveries.

The massive adoption of 3D printing technologies is also expected to revolutionize business models and plant operations. This model could be even more efficient than just in time. Although the adoption of 3D printing seems feasible at the component level, its adoption for the creation of entire modules will have to occur at plants given the complexity of these modules. Raw materials required for prototyping are usually never on time thanks mainly to delays caused by excessive inspection times at the borders. Typically, vendors have their raw materials located at the plant or very near in company-owned spaces, and this model physically consumes storage space, which translates into higher costs for manufacturing companies. Often, raw materials for the production of prototypes or very specific components (e.g., air bags, control computers, and fan blades) demand low quantities, and it is hard to find a supplier that provides just the quantity demanded. This forces companies to have warehouses on the U.S. side of the border, causing additional storage costs for manufacturers and inconveniences to the suppliers because inventories are not billed until they arrive at the plant for usage, typically located on the Mexican side of the border. In the future, an express line at the border crossings specifically for prototyping components could be a potential solution to such delays.

Steel and Mining

Interviews with supply chain managers in the steel and mining industry sector revealed that freight by rail has increased substantially and is expected to continue increasing for this sector. Among the biggest concerns of the industry are the availability of railcars, long travel times, and not enough origins-destinations offered by the current rail companies. Interviewees think that, even 30–50 years from now, steel will not be replaced as a construction material because of its metallurgical properties. However, improvements in other alloys will create a major product shift. The industry expects that repairing the current deteriorated state of the infrastructure in the United States will be the main driver of demand in the next decades, generating a boom in the industry and its related transportation and logistics needs. For the companies interviewed, most shipments going into Mexico are picked up by the customer by truck and rail at the company on the U.S. side, and the customer is in charge of moving the freight across the border. The carrier procurement and selection for trucks are performed through Internet-based freight-matching services. Overweight and over-dimensional loads are handled on a case-by-case basis. Although the truck is the most commonly used mode because it delivers the next day, this industry is already facing some transportation problems. For example, the shortage of U.S. drivers is a serious concern, hence the continued shift to rail.

Construction Materials

According to the construction materials executives interviewed, in the 1990s, construction companies started outsourcing their supply chain requirements to third-party logistics providers, consolidating their distribution network into a centralized warehousing and distribution facility. This resulted in the development of novel packaging solutions designed to not only protect the product but to increase storage, distribution, and construction efficiency. The evolution of transportation systems over the years has caused a profound impact on the way construction jobs are completed. Construction managers are now in reality supply chain managers, who must ensure that ever-changing inventory levels satisfy demand at all times in an optimal manner. The application of technological innovations to manage efficient inventory levels and timely logistics in a construction job has become one of the key profit drivers in the industry. The integration of global multimodal supply chains and changes in the fleet size of transportation companies, from just large trucks to smaller, smarter, energy-efficient vehicles,

now translates into low fuel costs and the ability to travel distances that were not cost effective before.

Transportation

Interviewees from transportation companies located in Mexico revealed that reshoring and nearshoring of various large manufacturing companies in Mexico are expected to substantially increase demand for freight transportation across the NAFTA regions. The level of investments in the automotive industry in Mexico has grown aggressively in the last few years, and this industry is one of the most important generators of freight, particularly for the movement of containers within North America and Asia. Changes in demographics and trade flows will also impact future freight transportation demand, and the only way to cope with it would be a shift to more efficient modes. The demand will continue increasing, and it is impossible to continue adding highway lanes to cope with the increased growth. Rail has the advantage of being sustainable and has a higher level of safety than truck, and by diverting freight from truck to rail, road maintenance costs are reduced. A substantial modal split from truck to rail is expected to satisfy demand for freight transportation across the NAFTA regions in the long run. More public-private partnerships can offer alternative funding mechanisms to expedite the development of the additional, capital-intensive rail infrastructure that will be required to serve future demand.

Texas's population is expected to continue growing, increasing demand pressures for the consumption and movement of freight. Potential solutions to move more with less equipment will need to be implemented (e.g., increasing the current truck size and weight limits or designating overweight corridors).

Regarding the usage of Texas' ports, most of the interviewees expect that due to demographic changes and shifting trade partners, trade lanes will change in the future, serving other maritime ports currently underutilized. Several ports in Texas have rail service but are not handling large amounts of cargo, and companies are looking at them as potential viable alternatives. Public and private infrastructure providers should plan to offer access to these smaller ports that require good and efficient land connections. These investments in the railroads will also benefit the highway sector because freight that is currently handled by truck could be diverted to rail, reducing road damage and congestion. Rail will continue growing because more

commodities are being containerized. This trend, with good service from the railroads, could provide a competitive alternative to roadway transport for some commodities.

Manufacturing

Increased security measures after the September 11, 2001, terrorist attacks have directly impacted border-crossing times. To help mitigate border-crossing delays, the U.S. government started a series of certifications and processes designed to expedite the border-crossing process for trustworthy Mexican manufacturing and shipping companies in compliance with applicable laws. The programs have helped to expedite the transborder movements of freight, and companies are already well acquainted with the certification and inspection processes. A general finding among the interviewees is that for most ports of entry, the infrastructure is inadequate and obsolete. For example, the number of primary and secondary inspection lanes available is not enough to keep traffic flowing efficiently. Another general finding is that the implementation of technology has advanced incredibly in most of the supply chain segments, except for the transportation and border-crossing parts. Some trucking companies in Mexico continue to operate old trucks or trucks without any connections to tracking and monitoring technologies, which prevents managers from achieving visibility of their entire supply chain. Moreover, some of the interviewees perceive that the implementation of tracking and monitoring technologies in new trucks is not one of the main priorities of the overall industry in Mexico.

Mexican demographics will have a young labor force for the next 10 years, and as its labor force matures, it is expected to increase consumption of goods (e.g., cars, homes, and appliances). Labor income levels and the location of such consumption patterns will have an impact on the levels of Texas's trade with Mexico and the main routes of its supply chains. Labor cost used to be one of the critical variables in site selection for manufacturing companies. However, educational attainment and skills are now more critical drivers since both are a key in the administration of robotic processes and automation technologies. The implementation of robotic processes and automation continues to spur the wave of innovation and is dramatically changing the way of doing business at every stage of the supply chain. In the next 20 years, this trend will become more notorious and will continue to displace human labor for robots. In addition to labor, robotic process automation is having an impact on contracting models; firms with automation processes have a competitive advantage. Robots can function anywhere, and

this translates into local control and minimization of issues with regulation and offshoring of data and intellectual property.

SUMMARY OF FORTUNE 500 AND MEXICAN MAQUILA INTERVIEWS

To better understand the factors that are used within the business models used by the corporations interviewed, Table C-1 shows the economic sectors included within the study and the relevant factors for each identified category. Based upon the data, the common factor that influences business models within the demographic category was the aging population factor. For global trade patterns, the most common factors were emerging markets, security concerns, and volatile commodities. Sustainability, alternative fuels, extreme weather events, and regulations were all factors that were noted within the environmental regulations category, with sustainability included for five of the six sectors that answered this question. Themes in the technology factors included computer-based routing systems, e-commerce, and the use of automation (robotic and vehicular).

Table C-1. Fortune 500 Companies and Mexican Maquilas Business Model Factors.

	Relevant Factors			
Economic Sector	**Demographics**	**Global Trade Patterns**	**Environmental Regulations**	**Technology**
Food and beverage	• Population growth • Consumer trends	• Global trade patterns • Volatile commodity prices	• Sustainability • Alternative fuels* • Climate regulations • Weather events	• Computer-based routing systems
Oil and gas	• Aging workforce • Suburban lifestyle	• Emerging markets • Security concerns	• Safety and environmental compliance	• Driver safety technology • Smart trucks • More efficient engines and hybrids
Manufacturing	• All factors • Young workforce (Mexico)	• International emerging markets • Global security concerns*	• Governmental regulations • Hazardous goods regulations • Sustainability* • Extreme weather events	• Online retailing • Computer-based route modeling systems • Just-in-time delivery • Robotic process automation (Mexico) • 3D printing (Mexico)
Retail	• All factors	• Emerging markets • Risk assessments	• Sustainability • Environmental regulations • Climate changes	• Data
Transportation	• Aging populations	• Sourcing concerns • Commodity volatility • Emerging markets	• Sustainability* • Extreme weather events	• E-commerce • Direct to consumer model • Smaller product sizes
Automotive	–	• Customs concerns	• Sustainability	• Direct pull orders • Green and ecofriendly technologies
Steel and mining	–	–	–	• Alloy developments
Construction materials	–	–	–	• Product evolutions • Autonomous vehicles at sites

** Noted in both the U.S. and Mexican interviews.*

Table C-2 provides details on the trends for how the factors from Table C-1 create changes in the freight system. With respect to sourcing patterns, the common trends across the economic segments were the minimization of distance between distribution centers and products, local sourcing of products, and a shift toward sustainability. Freight destinations had the common theme of emerging markets changing the destinations, but the specific markets were not consistent. Trucking was the common mode for current freight movements, and port issues and multimodal opportunities were the most common impacting factors for routing pattern and mode changes. The common factors that led to freight volume changes were seasonal volatility and increased demand. For value changes, a common trend was that products were becoming more expensive and that the cost of shipping was increasing.

Table C-2. Fortune 500 Companies and Mexican Maquilas Factors That Result in Freight Changes.

	Changes in				
Economic Sector	**Sourcing Patterns**	**Freight Destinations**	**Routing Patterns and Modes**	**Freight Volumes**	**Value**
Food and beverage	• Capacity limitations • Modal pricing advantages	• Weather • Legislation restrictions	• Due to extreme weather	• Negative weather impacts • Legislation and regulations	• Modal changes • Commodity prices • Global trade patterns
Oil and gas	–	–	–	• Seasonal	–
Manufacturing	• Minimizing distance between distribution centers and products • Sustainability • Local products*	• Demand based	• Mainly truck • Increased international demand leading to more air freight • Increased port activity • New products	• Seasonally volatile in spring • Increased product demand	• Products more expensive* • Cost of shipping increasing (domestic and international)
Retail	• Costs • Geopolitical climates • Sustainability • Human and worker rights • Supply chain complexities	• Emerging markets dominated by a growing middle class • Geopolitical climates	• Rail disruptions • Port issues • E-commerce • Shrinking lead times	• Demographic factors • Generational differences	• Customer needs • Sourcing decisions • Technology • Costs
Transportation	• Nearshoring/reshoring • Emerging markets • Panama Canal expansion • Delivery speeds	• Emerging markets in Asia	• New flight patterns • Regional hauling • Port issues* • Multimodal opportunities*	• Increased flights • Increased border freight	–
Automotive	• Minimizing distance between distribution centers and products	• Mexican manufacturing exports continuously to U.S. • Border-crossing delays	–	• Smaller material batches and more frequent deliveries desirable	–
Steel and mining	–	• Deteriorated U.S. infrastructure driving demand	• Mostly truck • Expected increase of rail	• Consistent	–
Construction materials	–	–	–	• Increasing from modular system	–

** Noted in both the U.S. and Mexican interviews.*

The final area of analysis for the Fortune 500 companies and Mexican maquilas was the future needs of the freight transportation system. The following were the noted future needs from the interviews conducted, which have been grouped with respect to commonalities (the number in parentheses is the number of segments that mentioned the need):

- Increased rail capacity (4), intermodal options (4), high-speed freight rail (2), increased refrigerated rail (1), and increased rail needs at the border and from Texas to other U.S. states (1).
- Increased ocean freight (2), expansion of ports that are underutilized (1), and better access to underutilized ports (1).
- Increased space for air freight at airports (1), more efficient air traffic control systems (1), increased export movements by air from Mexico (1), and drone allowances (1).
- Truck size and weight changes (1), alternative trucking configurations (2), lighter and stronger trucks (1), and labor shortages due to aging and underqualified drivers (2).
- More alternative-fuel options (3), safer and more efficient vehicles (1), and connected and autonomous trucking options (used in Mexico currently) (4).
- Dedicated lanes/roadways for freight and oversized/overweight freight for highway travel and to and from airports (1).
- Maintenance and upgrade of existing infrastructure (1), build-out of freight infrastructure at the border (1), infrastructure in sync with last-mile delivery (1), border-crossing infrastructure and technology synchronized on both sides (1), and more customs lanes and improved infrastructure (1).
- Long-term sustainable funding sources (2) and private-public partnerships to develop additional infrastructure needs (1).