Introduction

This white paper produced for the Texas Freight Mobility Plan (TFMP) explores an array of trends and issues likely to impact freight movements in Texas today and in the future. The issues are organized into five areas based on previous research about key forces driving changes to freight transportation, and issues identified through the TxDOT Statewide Long Range Plan Update.1, 2 The five areas to be discussed are:

- Economics
- Demographics
- Infrastructure Preservation
- Environment
- Technology

It is anticipated that the trends and issues identified in this report will be discussed, scrutinized and weighed-in upon by members of the Texas Freight Advisory Committee. The goal of this discussion is to achieve some level of consensus about which trends and issues are likely to have the highest impacts on freight movements in Texas over the next several decades.

Trends and Issue Impacts on Freight Transport: Effects on Flows

In early 2013, the Transportation Research Board (TRB) published a report prepared by a team of researchers from MIT who explored new ways to examine long term planning horizons for freight transportation. The research

<table>
<thead>
<tr>
<th>Potential Flow Events/Outcomes</th>
<th>Flow Impact Causes/Examples</th>
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<tbody>
<tr>
<td>A. Impact on Flow Origins</td>
<td>Changes to product sourcing, changes to the availability of raw materials and labor market competition. E.g. emerging economies.</td>
</tr>
<tr>
<td>B. Impact on Flow Destinations</td>
<td>Shifts in the locations for final product demands resulting from increases in population, consumer tastes, economic growth / decline and changes in wealth distribution.</td>
</tr>
<tr>
<td>C. Impacts on Routing</td>
<td>Changes affecting the path or route shipments take in moving from the point of origin to the consumer.</td>
</tr>
<tr>
<td>D. Impacts on Flow Volume</td>
<td>Increases or decreases in the amount of product movement by tonnage or value.</td>
</tr>
<tr>
<td>E. Impact on Value Density</td>
<td>Changes to the characteristics of the product(s) being shipped. Value density is a primary criterion for mode choice and network design.</td>
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Source: NCHRP 750, adapted by Olsson Associates

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included workshops with thought leaders and industry experts to examine forces affecting freight transportation 30 to 40 years into the future. The researchers concluded: “There are an unlimited number of potential events, trends, or occurrences that can happen in the future. It is almost impossible to identify, much less plan for, all of these potential events.” To deal with this uncertainty the researchers translated events effecting freight into a finite set of outcome types called Flow Impacts, detailed in Figure 1.

**Economics**

Texas is a leader in many measures of economic competitiveness. Its Gross State Product (GSP) is approximately $1.4 trillion, second in the U.S. behind California. There are a myriad of factors that can be used to measure economic competitiveness, but generally, Texas’ natural advantages like large size and population, central location, Gulf coastline, and energy resources, combined with its massive infrastructure, low taxation and cost of doing business, make it a leader. According to Forbes’ list of Best States for Business, Texas ranks first in ‘Economic Climate’, second in ‘Growth Prospects’ and seventh overall. Also, 52 Fortune 500 companies and 116 of the largest 1,000 public and private companies in the country are headquartered in Texas, including AT&T, ExxonMobil, and Dell.

**NAFTA Trade**

Much of the U.S. trade with Canada and Mexico can be attributed to the North American Free Trade Agreement (NAFTA). This agreement came into force in 1995 and removed trade barriers between Canada, the United States, and Mexico. Mexico is Texas’ largest trading partner, making up 35.7% of Texas’ total exports; Canada is second at 9% and China is third at about 3.8%. From 2011 to 2012, trade with Mexico from Texas increased 8.5% while trade with Canada increased 7.8%. In contrast, exports to China experienced a decline of -5.9% over the same period. The top commodities being exported to Mexico from Texas are Computer and Electronic Products (23.4%), Petroleum and Coal Products (15.3%), Transportation Equipment (12%) and Chemicals (11.3%). Maintaining and growing this trade relationship with Mexico relies on maintaining adequate capacity and increasing efficiency of the Texas transportation network, especially near border crossings.

**Emerging Markets**

As global trade evolves, 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 U.S. exports. The ‘BRIC’ countries—Brazil, Russia, India, and China—have been the cornerstone markets of increased global trade. Africa is also identified as an emerging market, but their impact is often measured on a continent scale instead of individual countries. As Figure 2 shows, significant growth has occurred in exports from Texas to BRIC countries and the top 5 African nations since 2005.

There is no universal definition of an emerging market, but generally, the most widely used factors include GDP growth rate and per capita GDP growth rate. By this metric China’s GDP growth rate of nearly 8% in 2013 (compared

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7Ibid.
to about 3% for the U.S.) characterize it as a trade market that continues to emerge, despite its size and projections of when it will overtake the U.S. as the world’s largest economy.\(^9\) As China grows, however, its lack of domestic oil resources will require it to increase imports. Texas is a potential trade partner, but currently the majority of China’s oil imports come from the Middle East.\(^10\)

To support the growth in exports the U.S. Department of Transportation is investing in freight transportation infrastructure through the TIGER (Transportation Investments Generating Economic Recovery) program. So far, $354 million in TIGER grants has gone to 25 U.S. port projects from coast to coast.\(^11\) One freight project in Texas received a TIGER grant in 2013: the Port of Houston Authority, which won $10 million towards the construction of the Bayport Container Terminal.\(^12\)

**The Panama Canal**

The Panama Canal, completed in 1914, created one of the most important trade routes in the world, linking the Atlantic and Pacific Oceans. After nearly a century the canal is undergoing a $5.25 billion dollar expansion to accommodate more and larger ships. When the expanded canal opens in 2015, the new locks will allow for deeper, longer and wider ‘New Panamax’ vessels, essentially doubling existing throughput capacity (Figure 3). The expansion will reduce Canal delays, and potentially reduce shipper costs.

The expansion of the canal has spurred research interest across the country. In Texas, the Panama Canal Working Group studied the expansion’s impact on the state and had three principal findings in its 2012 final document:\(^13\)

1. The Panama Canal expansion...represents opportunities to expand Texas’ position as a global gateway for the nation. By providing a low-cost, reliable, safe, secure, multimodal, and environmentally sustainable supply chain, the state can increase its global trade, create new jobs, and expand the economy of the state and nation.

2. As the leading goods export state in the country, Texas is well positioned to take advantage of the Panama Canal expansion and other opportunities to increase the export of dry bulk, liquid bulk, general and break bulk cargo, and containers to existing and new markets. Commodities in these general categories include agricultural produce, coal, value added manufacturing products, petrochemical and chemical products, military cargo, paper products, consumer goods, and other products. The emerging LNG export market resulting from energy developments in the state represents a major opportunity.

**Figure 3: Container Ship Size Comparison**

Evolution of Container Ships

<table>
<thead>
<tr>
<th>Type</th>
<th>TEU Range</th>
<th>Length x Width x Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Container Ship</td>
<td>500 - 800</td>
<td>137x17x9</td>
</tr>
<tr>
<td>Fully Cellular</td>
<td>1,000 - 2,500</td>
<td>215x20x10</td>
</tr>
<tr>
<td>Panamax (1980-)</td>
<td>3,000 - 3,400</td>
<td>250x32x12.5</td>
</tr>
<tr>
<td>Panamax Max (1985-)</td>
<td>3,400 - 4,500</td>
<td>290x32x12.5</td>
</tr>
<tr>
<td>Post Panamax (1988-)</td>
<td>4,000 - 5,000</td>
<td>285x40x13</td>
</tr>
<tr>
<td>Post Panamax Plus (2000-)</td>
<td>6,000 - 8,000</td>
<td>300x43x14.5</td>
</tr>
<tr>
<td>New Panamax (2014-)</td>
<td>12,500</td>
<td>366x49x15.2</td>
</tr>
<tr>
<td>Triple E (2013-)</td>
<td>18,000</td>
<td>400x59x15.5</td>
</tr>
</tbody>
</table>

Source: The Geography of Transport Systems, Hofstra University

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\(^12\)USDOT. http://www.dot.gov/tiger

\(^13\)Report from the Panama Canal Stakeholder Working Group, November 2012
3. To increase global trade and economic development, Texas must develop processes that provide a transportation system focused on commerce, including Texas ports, the Gulf Intracoastal Waterway (GIWW), the roadway system, the rail system, and the pipeline network. It is critical that Texas accelerate investments in freight transportation infrastructure to grow commerce and increase the tax base of the state.

The Working Group noted that while it’s clear that the Panama Canal expansion will have an impact on Texas, the scale and timing are not known, but are anticipated to be positive. However, a key theme noted throughout the Final Report was that the State should continue to take proactive steps to take advantage of the Panama Canal Widening. For example, the Final Report recommended:

“TxDOT should remain focused on trade-related improvements. TxDOT, working with its partners, has numerous projects in different stages of planning, design, and construction that address critical transportation needs in the state. Many of these projects focus on key trade corridors and connections to Texas ports...TxDOT should continue to advance these projects in a timely fashion to address freight flow, safety, security, congestion, and environmental issues, and to strengthen Texas’ position in global trade.” 14

A March 2013 study from the Center for Transportation Research agreed with the findings related to port and marine planning of the Working Group.15 The report also notes that the basic question about Panama Canal impacts on Texas ports remains difficult to estimate in the short to medium term.

Figure 4 notes the 2012 corridors for containerized Texas imports and exports. By analyzing these corridors, the study found that “since shippers benefit from corridor choice and it is clear that Texas is not dependent on a single corridor, but rather, its economy will benefit from corridor competition from multiple routes based on market forces and non-cost-related needs on the part of the customer.”16

Port and Border Security/Efficiency

Border crossing security and efficiency are increasingly important issues for Texas due to U.S. trade with Mexico. Security processing is often identified as a key reason for delays at the border and delays at points of entry which are costly both economically and environmentally. Port security is also important due to containerized imports and hazardous materials (such as petrochemicals) that are handled at Texas ports.

A number of efforts have been introduced at the federal level to increase efficient border security, including the Container Security Initiative (CSI), the Secure Freight Initiative, and the Customs Trade Partnership against Terrorism (C-TPAT).

14Report from the Panama Canal Stakeholder Working Group, November 2012
15Evaluating the Impacts of the Panama Canal Expansion on Texas Gulf Ports, Center for Transportation Research, 2013.
16Evaluating the Impacts of the Panama Canal Expansion on Texas Gulf Ports, Center for Transportation Research, 2013.
CSI works with foreign governments to examine high-risk containers at foreign ports before departing for the US. Currently 58 ports are participating accounting for nearly 85% of all US-bound container traffic. The Secure Freight Initiative builds on CSI to specifically address potential nuclear threats. The C-TPAT partners with over 10,000 stakeholders around the world to pre-screen cargo entering the country; the participants represent over 50% of US imports by value.

Texas has developed its own program, the Border Safety Inspection Facility (BSIF) program (Figures 5 and 6), which consists of funding and construction temporary and permanent border inspection facilities at locations all along the Mexican border. The goal of these facilities is to provide an efficient method of inspecting and weighing commercial vehicles entering the US. There are 8 sites are included in the BSIF Program, located in El Paso, Ysleta, Eagle Pass, Laredo, Pharr, Los Indios and Brownsville.

Trusted shipper programs allow carriers who meet criteria determined by the trading countries to register, resulting in less scrutiny at the border. Programs like the Free and Secure Trade (FAST) lanes are used by C-TPAT to expedite border crossings and reward safe and well known carriers. Research conducted by the TTI found trusted shipper programs have been successful at reducing in reducing wait times; but carriers can be reluctant to join and share data. In recent years, the United States and Mexico have worked to improve collaboration on border issues including initiatives founded on co-responsibility, collaboration between customs agencies, innovation and expanding trusted shipper programs. For example, C-TPAT’s FAST lane program works with Mexico’s New Scheme of Certified Companies.

Texas convenes a Border Trade Advisory Committee to provide a forum between TxDOT, the governor, MPOs, ports of entry, universities, and city and county officials, among others, to evaluate the effect transportation choices have on border trade and communities. This Committee produces reports, the most recent in 2012, detailing the status of current programs, opportunities and threats to the system, funding issues and future outlook of border trends. Texas realizes the importance of border capacity, efficiency and security on the economic vitality of border communities as well as the state and nation. It is critical to continue collaborative efforts with Mexico and invest in capacity, technology and security upgrades where appropriate to ensure trade thrives and freight of all modes is able to freely and efficiently move across the border, throughout the state and beyond.

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Using technology at border crossings and ports is one way to enhance both security and efficiency without having to build large, expensive capacity improvements or other costly infrastructure. Federal security programs like the Secure Freight Initiative already employ technology which can scan and detect radioactive material in real-time, ensuring no nuclear material is traveling inappropriately.23

Texas’ Border Safety Inspection Facility (BSIF) program uses Intelligent Transportation Systems (ITS) strategies like weigh-in-motion (WIM) and dimension-in-motion (DIM) components so trucks do not have to stop, dynamic messaging signs to inform drivers, and a flow manager to ensure traffic flows smoothly.24 The entire system is synthesized into one software system for efficient and effective management by employees. Depending on if the truck passes or fails certain points of inspection, the software diagrams their route and what steps are to be taken to rectify the issue. Cameras are installed at various points and accessible from the software as well.

Port security uses a wide array of technologies including X-ray and Radiation Portal Monitors (RPM), intelligent video systems, crane-mounted sensors, and Radio Frequency Identification (RFID) tags, among others.25 Ports are also beginning to use strategies similar to how the Federal Aviation Administration (FAA) monitors all US air traffic, using an integrated coastal radar system to better understand and protect the borders as well as increase maritime safety in case of an emergency.

Demographics
Population Trends
Freight is a demand driven activity; more people translates to more consumption of goods, commodities and services which increases freight activity. The Texas State Data Center (SDC) has developed population projections for the next several decades. There are 3 migration scenarios and 0.5 migration represents the midpoint of the 3. Figures 7 and 8 present the SDC’s mid-range 0.5 net migration projections of county population change between 2010 and 2040, overlaid with forecasted

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roadway level of service (LOS) in 2040 (LOS represents the ratio of volume to capacity). Key observations about the projections include:

- Counties with the greatest percentage increase are situated in the current urban areas of Austin, Dallas, San Antonio, and Houston; but 35 counties are projected to increase by 50% or more, with a substantial increase in the traditionally rural counties of West Texas. The Panhandle Counties are projected to have the least population growth.

- While percent growth can provide a useful perspective, it can fail to capture the magnitude of growth in larger urban areas. The counties with the greatest projected net change are: 1) Harris (+1,819,299), 2) Collin (+902,772), 3) Dallas (+777,898), 4) Tarrant (+776,154), 5) Bexar (+752,101), 6) Denton (+733,839), 7) Fort Bend (+677,716), 8) Hidalgo (+582,411), 9) Montgomery (+497,395), and Williamson (+490,593). The relative age of the population skews from younger to older consistently among the 3 scenarios. The percent of the population over 60 increases by an average of 10%, while the percent of population between 20 and 60 decreases by an average of 9%.

- The vast majority of recent population growth has occurred in the major metropolitan areas and this will continue to be the case in the future.

- While congestion is proportionately greater in the urban areas, there are key connectors between cities, from ports to cities, and border areas that are forecasted to be “severely congested”. Examples include: I-35 between Dallas, Austin, and San Antonio, I-10 between San Antonio and Houston, and I-45 between Houston and Dallas. It is likely that the congestion is due to substantial urban area growth coupled with growth along the corridors themselves.

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According to the USDOT the annual tonnage of freight moving per capita is expected to increase from 55 tons in 2010 to 70 tons in 2040.27 Texas' 2012 population was 26.1 million residents (8% of US total).28 The state's share of the nation's shipments and sales are even greater than its population and housing stock. Texas had 11% of manufacturer's shipments and 10% of merchant wholesaler sales in 2007 dollars. These factors suggest that pressures on the transportation system will grow, including the freight system.

**Population Trends and “Mega-regions”**

Texas is also home to a major Mega-region, the “Texas Triangle”, which is framed by Dallas-Fort Worth, San Antonio, Austin, and Houston. Mega-regions have been described as “the name given to one or a grouping of several urban areas, linked by social, economic, demographic, environmental, and cultural ties.”29 Attention has been given to the concept of mega-regions as geographers, planners, and economists have realized that mega-regions, rather than particular cities, states, or nations, are the real driving force in the world economy.

Ten mega regions in the United States have been identified by the Regional Plan Association in their “America 2050: A Prospectus”.30 These mega-regions (Figure 9) are where, by mid-century, “more than 70 percent of the nation’s population growth and economic growth is expected to take place,” with an increase movement of goods, people and capital between those regions. As these mega-regions increase their roles in the national and global economy, pressure and increased congestion for ports, highway facilities, railroads, intermodal yards, and other freight facilities will only increase. While specific area delineation differs, by one count, mega-regions in the United States account for only 30 percent of the geographical area, but 77 percent of both population and employment, 81 percent of gross regional product, and 92 percent of Fortune 500 Companies’ revenue (all 200831). Effective freight planning will take into account not only movement within each of these mega-regions, but also freight movement from one-mega-region to other mega-regions.

![Emerging Mega Regions](image_url)

**Figure 9: Emerging Mega Regions**

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30America 2050 Prospective, page. 4.
In Texas specifically, its 66-county area, including 7 metropolitan areas and multiple micropolitan areas comprises the “Texas Triangle.” It is estimated that “By 2050 about 35 million people, or 70 percent of the population of Texas, will live in the Texas Triangle. Three of the nation’s 10 largest cities are in the Triangle, including Houston, which has a port that handles more foreign tonnage than any other U.S. port. Efforts to create a NAFTA superhighway from Mexico to Canada could create a developed corridor through San Antonio, Austin, and Dallas.32

Infrastructure Preservation

The Texas freight transportation system is a complex network of roads, bridges, airports, railroads, ports, and other elements that have been developed over many years. This infrastructure has a replacement value in the billions of dollars. Maintaining the structural integrity, functionality, and efficiency of these systems is essential to supporting the Texas economy. There are several trends and issues impacting the Texas freight transportation infrastructure.

Port and Waterway Maintenance

“Handling approximately 564 million tons of foreign and domestic cargo annually, Texas ports rank first nationally in goods exports and waterborne commerce. Texas ports account for 19 percent of U.S. port tonnage... Texas ports create nearly 1.4 million jobs and generate over $82 billion in personal income annually. The maritime cargo activity at the public marine terminals in Texas generated $277 billion in economic value to the state in 2011.”33

With over 300 miles of coastline along the Gulf of Mexico, Texas ports (Figure 10) are critical infrastructure serving the state’s economy. Texas has eleven deep-draft ocean ports. Texas also has ten shallow ports handling mostly barge

Figure 10: Texas Ports

Source: TxDOT

traffic on the Gulf Intracoastal Waterway. The US Army Corps of Engineers is responsible for maintaining navigation channels, including the Gulf Intracoastal Waterway, and, when approved by Congress, pays between 50-65% of the cost of channel deepening or widening project.\textsuperscript{34} Port capacity could be greatly strained with additional traffic which is expected in the future especially at container terminals with the expansion of the Panama Canal. It is estimated that $5.75 billion is needed for maintenance and operations of the ports through 2035 (not including expansions necessary to handle larger New Panamax ships at some Texas ports).\textsuperscript{35}

Port maintenance funding was adjusted in 2001, when “the Legislature amended the transportation code to create “Funding of Port Security, Projects, and Studies”, which addresses three main subjects, the Port Authority Advisory Committee, the Port Access Account Fund, and the Capital Program. The Transportation Commission appoints seven members of the Advisory Committee, who develops the Capital Program annual report. The report details port projects and funding needs submitted by Texas public port facilities, and the Port Access Account Fund provides a means for the state to help fund port expansion, upgrades, and maintenance.”\textsuperscript{36}

Highway and Bridge Maintenance

TxDOT’s Statewide Long Range Transportation Plan (LRTP) notes that Texas has more than 51,000 bridges to maintain. The Texas Transportation Commission established the goal of achieving 80 percent of Texas bridges being rated in good or better condition by September 2011. As of 2006, the most recent year of data available, the actual percentage of bridges in good or better condition was 77%. While there has been a decrease in the number of deficient bridges, there remain a substantial number of bridge structures on the system that will reach their predicted lifespan during the next several decades.

Texas must also maintain thousands of miles of Texas highways and other public roads to maintain the traveling surface. As demand increases, particularly truck traffic, the wear and tear on Texas’ highways increases. A significant difference exists between TxDOT’s projected maintenance funding for 2010–2035 and the pavement maintenance funding needs recently identified by The University of Texas Center for Transportation Research.

Although TxDOT is close to meeting its goal of 90 percent of pavements rated as good or better, current trends in funding may lead to a rapid decline in overall average statewide pavement rating. This decline, given current funding trends, will cause Texas’ pavement scores to average less than 10 percent good or better by 2035.

Texas’ surface transportation funding has relied on traditional revenue sources (taxes and fees), with infusions of one-time and temporary revenue streams. The Texas 2030 Committee noted that in recent years the state used $6 billion in bonds, American Recovery and Reinvestment Act ($2.24 billion), and Toll Road Rights ($2 billion) for maintenance and improvements. The 2030 Committee also estimated pavement quality, bridge conditions, and rural congestion, shown in Figures 11 and 12. Though the specific condition characteristics are unique for pavements and bridges, the letters in the legend of each graph represent four possible scenarios that were established by the Committee, defined as follows: F=Unacceptable conditions; D= Worst acceptable conditions; C= Minimum competitive conditions; B= Competitive conditions.

\textsuperscript{34}Texas 2030 Committee Final Report
\textsuperscript{35}Ibid
and B=Continue 2010 conditions. For example, in Figure 11, the graph shows that when limited funding leads to an ‘F’ scenario of Unacceptable conditions, the percent of pavement rated fair or worse quality increases to almost 90% by 2035. In the case of the ‘C’ scenario, where minimum competitive conditions are maintained, approximately 30% of pavements would be rated in fair or worse quality.

**Domestic Oil Production & Hydraulic Fracturing**

Oil has been a major industry in Texas since the early 20th century. Oil spurred the rapid growth of cities like Houston and the development of refineries and other petroleum related facilities throughout the state. However, production totals had been steadily declining over the last couple of decades until new technologies were broadly implemented, namely the combination of hydraulic fracturing (fracking) with horizontal drilling. Figure 13 shows that Texas is currently leading all U.S. states as the top oil producer. During April 2013, Texas produced 2.45 million barrels per day (bpd) compared to 800,000 bpd for North Dakota.\(^{37}\) Texas oil production is expected to exceed three million barrels per day (bpd) by the end of 2013, to become the 8th largest oil-producing entity in the world.\(^{38}\)

Oil and gas production by fracking increases highway system demands due to the needs for trucks supplying well equipment, frac sand, water and chemicals. The Task Force on Texas’ Energy Sector Roadway Needs notes that one oil or gas well requires 1,184 loaded trucks to start production, 353 loaded trucks a year to maintain production, and 997 loaded trucks once every five years in order to re-frack the well. This level of heavy truck activity correlates to a cost of $4 billion a year to repair state and local road infrastructure from drilling damage.\(^{39}\)

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Another impact on the Texas transportation network is the sand used for hydraulic fracturing is typically shipped by rail from other parts of the United States and then trucked to the wells. One example of the investment railroads are making to support fracking-based energy development in Texas is the BNSF facility in Sweetwater, Texas currently in development. The 75-acre logistics facility is being built to handle sand, aggregate, pipe, and other drilling materials shipping by rail to the oil fields in West Texas.  

Modal Productivity

During the 1960s and most of the 1970’s freight was a highly regulated industry. Economic regulations that governed railroads, motor carriers, ocean carriers and airlines largely stifled competition and productivity innovation. Beginning with the Railroad Revitalization and Regulatory Reform Act in 1976, the U.S. Congress passed a series of modal deregulation bills that culminated with the Ocean Shipping Reform Act of 1988. Most of the remaining regulatory structure which affects freight transportation in the US focuses on safety, security and the environment. Since the 1980’s numerous studies have examined the impact of economic deregulation in the various freight modes. Most studies concur that deregulation had significant impacts on freight industries including lower rates and more service options, which decreased choices available and/or the level of service for some shippers. Overall, however, impacts have been view as positive especially by the railroad industry:

“By the 1970s, decades of increasingly stringent government regulation had brought the U.S. freight rail industry to the brink of ruin. Today, though, America’s freight railroads are the envy of the world... What brought about this change? Congress passed the Staggers Rail Act of 1980, which instituted a system of reasonable regulation in the rail industry, ushering in a new era in which railroads could largely decide for themselves... what routes to use, what services to offer, and what rates to charge. Since Staggers, average rail rates have fallen 44 percent, train accident rates are down 80 percent, rail traffic volume has nearly doubled, and railroads have reinvested $525 billion...back into their systems.”

Since deregulation most freight modes have seen fairly dramatic increases in the productivity of their operating assets and labor. Following deregulation, changes in train technology in the railroad industry, for example, allowed railroads to eliminate the caboose and reduce train crew size. Also, during the past several decades unit trains grew longer (unit trains have typically increased from 70-80 cars up to 120 cars) and introduction of the well car or double-stack car have allowed containers to be stacked two-high: Class 1 railroads have made major investments to remove overhead clearance issues on heavily used container train routes over the past several decades. In 2010, the Union Pacific Railroad conducted a test run of a 3.5 mile long unit train containing 286 cars from Texas to Los Angeles. Similar productivity gains in asset capacity have been seen in the container shipping industry. In 1980, the first container ship exceeding 4,000 TEU (twenty-foot equivalent units), began operation and was the largest ship of its kind. In 2011, Maersk container shipping line ordered 20 Triple-E class ships capable of carrying 18,430 TEU. The capacity of air craft used for commercial cargo operations have also increased in capacity and efficiency over the past several decades due to the introduction of wide-body aircraft. Boeing Company which produces an annual World Air Cargo Forecast suggests that by 2031, the world air cargo fleet with grow by 80%, with the share of wide-body aircraft increasing from 31% to 36% of the total fleet.

Highway freight transport is a notable exception to the type of growth witnessed by other modes. On the federal highway system, the last significant increase in truck load or carrying capacity occurred in 1982, when Congress passed the Surface Transportation Assistance Act, and raised the weight limit on Interstate and National Truck Network highways from 73,280 lbs. to 80,000 pounds, and also established dimension standards for tractor-trailer semi combinations. One means of comparing productivity between modes is to examine labor productivity. The chart

in Figure 14 shows the growth in labor productivity by mode since 1987. During the last transportation reauthorization (MAP-21), Congress called on the USDOT to conduct a study on specific areas of federal truck size and weight limits, their operation and their impacts. The results of this study are due to Congress prior to the next transportation reauthorization.

![Figure 14: Transportation Labor Productivity by Mode, 1987-2011](source: US Bureau of Labor Statistics, graphed by Olsson Associates)

**Environment**

**Alternative Energy Resources**

In addition to the vast oil resources, Texas is the leading wind energy producer in the United States, with 10,570 megawatts (MW) of capacity as of September 2013.\(^43\) Wind accounted for 9.2% of electricity generation in the state in 2012.\(^44\) By the end of 2014, the Electric Reliability Council of Texas (ERCOT) projects that number could reach 14,000 MW as several new large-scale wind farms are planned to come online. Texas has a natural advantage in wind production due to its geography, where the average wind speed at an elevation of about 260 feet (80 meters) in West Texas and the Panhandle approach 30 feet (9 meters) per second (Figure 15, on the following page).\(^45\), \(^46\) While this growth in generation capacity will continue for a few years, it may slow in the future due to expiration of the Federal Renewable Electricity Production Tax Credit (PTC) at the end of 2013.\(^47\)

Texas has supported the wind generation industry with policies such as a Renewable Portfolio Standard, which requires 10,000 MW of renewable generation by 2025.\(^48\) In 2005, the Texas Legislature also passed the Competitive Renewable Energy Zone (CREZ) initiative designed to build transmission capacity to allow Texas to add wind capacity. In 2008, five geographic areas were designated as CREZs which became the focus for transmission improvements.

Wind turbine construction places specific demands on the transportation system. Due to the extreme size and length of wind turbine components, such as blades which arrive in one piece, transporting these components from manufacturer to site presents some challenges. In the long term, if wind energy development continues, Texas may need to consider adjusting road building standards in the CREZs or devote specific oversize/overweight (OSOW) routes along the supply chain so wind turbines can safely and efficiently reach the Panhandle as well as central and west Texas.

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\(^45\)Wind speed is universally measured in meters, producing a consistent method for estimating wind energy generation potential; 80 meters is the most commonly used height at which wind speeds are compared.


\(^47\)U.S. DOE Department of Energy Efficiency and Renewable Energy.

Alternative Transportation Fuels
Compressed Natural Gas/ Liquefied Natural Gas

In 2011, transportation use accounted for less than 1% of the natural gas consumed in the United States. However, the exploration of shale-based natural gas resulting from advances in hydraulic fracking recovery methods has recently driven down the price of natural gas. Fracking recovery technology has also significantly driven up proven natural gas reserves in the United States. With retail diesel prices hovering around $4.00 per gallon since 2010, natural gas is currently about 40 percent less expensive than diesel on a per gallon equivalent basis. Natural gas use emits approximately 25% less greenhouse gas emissions than diesel fuel. Consequently, commercial trucking fleets have begun converting to compressed natural gas (CNG) for short-haul operations, and liquefied natural gas (LNG) for long-haul operations. Companies with large fleets that have made commitments to CNG/LNG include UPS, Waste Management, A T&T, and Coca-Cola, to name a few.

For Texas, further adoption of natural gas for transportation will require more filling stations and widespread distribution and awareness by policymakers. Currently, most filling stations, like those being built by UPS, are paid for and used privately, but if demand for CNG and/or LNG fueling stations continues to grow, the state or municipalities may need to consider policies to attract or allow for fueling stations so that more businesses (and, potentially, residents) can access this fuel.

Biofuels

Biofuels have the potential to reduce carbon emissions, reduce reliance on foreign oil, and create rural economic development. For freight transportation, biodiesel is most important biofuel (as opposed to ethanol, for example) because at lower blends with petroleum-based fuel (20 percent or less), no modification of current diesel engines is required. Increasing the use of a biodiesel blend has shown potential to be a short-term, relatively low cost way to reduce freight-related emissions (including nitrous oxides (NOx) and particulate matter, PM-10), which could be attractive to areas of the state such as Dallas-Fort Worth, El Paso, or Houston which are in nonattainment under USEPA air quality standards.51

Texas is the nation’s largest producer of biodiesel for transportation with about 20 biodiesel plants in the state and a total production capacity of over 100 million gallons per year.52 The Texas Council on Environmental Quality (TCEQ) created the Texas Low Emission Diesel Program (TxLED) to increase biodiesel use and to reduce nitrogen oxide levels in Texas. As of 2011, this program allows biodiesel to be added to any current compliant fuel at any ratio without additional monitoring.53 The effect on Texas transportation networks is likely limited as most existing trucks can use B20; however, continued adoption and investments in biodiesel infrastructure and distribution around the state make it a trend of which planners and policymakers should be aware. Biodiesel can also be used in freight railroad locomotives and railroads like BNSF are currently participating in long-term trials with B20.54 Adoption and use of biodiesel is one of many strategies that are being used to improve air quality; alone it is unlikely to be able to make a significant difference in nonattainment areas unless the industry dramatically increases in production and consumption.

Air Quality

The U.S. Clean Air Act (CAA) regulates areas that do not meet the standards for criteria pollutants under the National Ambient Air Quality Standards (NAAQS). In Nonattainment Areas federal law requires state and local governments to develop and implement plans for bringing these areas back into compliance. Texas has three areas currently in nonattainment: El Paso, Houston-Galveston-Brazoria and Dallas-Fort Worth.55 There are also other areas operating under ‘maintenance’ State Implementation Plans (SIPs) which often have provisions affecting the transportation network (Figure 16, on the following page).

TCEQ coordinates with TxDOT and local MPOs to develop a motor vehicle emissions budget as part of the SIP. If a federally-funded transportation project is not consistent with air quality goals under the SIP, the planning and implementation process can be significantly delayed. As is relates to freight, project delays only prolong bottlenecks for truckers (who carry goods to other parts of the system), and restrictions on traffic in general can also affect trucks. Air quality regulation under the CAA is yet another factor driving environmental improvements in truck emissions and fuel use. The CAA regulations also are driving optimization of use across modes, such as rail or barge, whose fuel use and emissions are significantly lower per ton that trucking. Additionally, USEPA is adopting more stringent exhaust emission standards for large marine diesel engines; the overall strategy includes adjusting CAA standards as well as

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55Texas SLRTP 2035 Chapter 8.
implementing international standards. By 2030, the measures are expected to reduce annual NOx emissions in the U.S. by approximately 1.2 million tons and particulate matter (PM) emissions by 143,000 tons.56

One example of a shift in freight transportation due to air quality factors was a ban on operating construction equipment from 6:00 to 10:00am in warmer months implemented in Dallas Fort Worth as part of the State Implementation Plan for ozone published in 2001. This included dozers, loaders, water trucks, dump trucks, backhoes, other diesel powered vehicles and machines; requiring construction deliveries and waste management trucks, among others, to re-route and/or adjust the timing of trips despite the preference for operating during cooler morning hours.57

**Technology**

**Dedicated Freight Infrastructure**

Today technology is often associated with advance electronics, but traditionally technology is more broadly defined as the application of knowledge to the creation and use of technical means and their inter-relation with life, society and the environment.58

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As freight volumes have dramatically increased across the U.S. during the past several decades, concepts for dedicated freight infrastructure, such as dedicated truck lanes has increasingly entered the transportation lexicon. Dedicated truck lanes physically separate commercial vehicles from passenger vehicles or mixed traffic flows. In recent years a number of states, including California, Florida, Georgia and Texas have examined dedicated truck lane concepts, as have a number of multistate corridor coalitions such as I-70 and I-10. Figure 17 shows an example of a dedicated truck lane. While highway lanes dedicated to commercial vehicles may not seem like advanced technology, separating vehicle streams introduces a new level of complexity in highway design (e.g. on / off ramps) and operations (dealing with incidents or breakdowns).

To date, few examples exist of operating dedicated truck facilities, and those that do exist tend to be relatively short routes serving ports or key border crossings. The concept of long-distance truck lanes is frequently tied to tolling as the means of raising revenue to support construction. The trucking industry has expressed strong opposition to tolling truck lanes due to high administrative costs compared to traditional fuel taxes and the reluctance or refusal of shippers to reimburse carriers. Some dedicated truck lane concepts would also force trucks off infrastructure constructed in part with taxes and fees already paid by the industry. Benefits associated with dedicated truck-lanes include significant safety gains, the potential of adopting high productivity vehicle (HPV) configurations and the possibility of infusing advanced technologies that fall under the umbrella of Intelligent Vehicle Initiatives (IVI). HPV configurations such as heavier trucks with more axles or longer combination vehicles (LCVs) have been proposed as one means of off-setting the costs of tolls often associated with dedicated truck facilities.

The Texas A&M Transportation Institute (TTI) has been advancing the concept of an elevated structure dedicated solely to the transport of freight called the Freight Shuttle System (FSS) shown in Figure 18. Autonomous transporters carry truck trailers or containers along an elevated guideway designed to be located along the median of an existing right-of-way, usually a freeway or highway. The transporters use electrically-powered linear induction motors that power the transporters efficiently and without additional emissions; guideway construction uses a technique requiring no road closures.59

The pilot location proposed for implementation of the FSS is Juarez, Mexico to El Paso, Texas, a distance of 11.7 miles. Freight Shuttle International (FSI) has signed a letter of intent with the City of El Paso, the City of Ciudad Juarez, and the Regional El Paso Economic Development Corporation60 to privately finance and build the project.61 If and when it is completed, the FSS could change the dynamic of short and

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60 The El Paso Regional Economic Development Corporation (REDCO) merged with the Paso del Norte Group to form the Borderplex Alliance in early 2013.


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**Figure 17: Example of Dedicated Truck Lanes**

**Figure 18: Freight Shuttle System Autonomous Transporter and Guideway**

Source: TTI
medium-range freight shipments by reducing congestion and deterioration of roads, increasing import and export capacity, and easing the infrastructure burden on public tax dollars.

3D Printing

Three-dimensional printing, or 3D printing, is a term for a process in which a three-dimensional solid object is produced from a digital model. Many investors and futurists have called 3D printing a “game changer”:

“From my vantage point, 3D Printing is right up there as one of the most exciting innovations I’ve seen in the 20 years I’ve been around here. I think it’s going to change the way goods are manufactured across many industries.”

- Hugh Evans, Vice President, T. Rowe Price Associates

There are many advantages to 3D printing over traditional manufacturing processes. First, it requires less raw material as no material is cut, drilled or removed to shape the object. Complex and highly customized products (like those required by the medical and aerospace industries) are good candidates for this technology because products can be made lighter while maintaining strength.\(^{62}\) 3D printers can also create objects that were previously impossible or extremely difficult to make through traditional methods—for example, a human organ.\(^{63}\) Those taking longer terms views of 3D printing have suggested that it could have major implications for the future of global supply chains.

Reducing economies of scale and substituting technology for low cost labor are examples of potential manufacturing and associated supply chain impacts. A 2012 report entitled The Implications of 3D Printing on Global Supply Chains by Transport Intelligence detailed some of the other possible effects, including: Near-sourcing of goods to North America from China, reducing warehousing requirements due to customization of products, an emergence of a market to store and move the necessary raw materials, and a reinvented shopping experience where retailers “become ‘shop windows’ for manufacturers, keeping no stock of their own.”\(^{64}\) All of these represent potentially dramatic changes for the global freight market.

Another major benefit of 3D printing is that it lowers the costs and risks of innovation. Not only can prototypes be created, altered and re-printed in hours instead of days or weeks, final, end-use products can be printed and customized for customers. This allows an inventor or entrepreneur to grow their business and make a profit without needing to manufacture thousands of units.\(^{65}\) Other benefits include energy savings, labor savings, and occasionally time savings as well.

Conclusions and Next Steps

“The future rarely moves in predictable, incremental ways. Often seemingly small changes in technology, demographics, regulations, economics, or a myriad of other factors have dramatic and unintended impacts on how any organization (public or private) plans and operates. These nonlinear impacts are very difficult to predict using traditional forecasting methods and techniques since they, by definition, do not follow any historical patterns.”\(^{66}\)

The purpose of identifying major trends and issues likely to impact freight transportation in Texas in the foreseeable future is to provide additional information about the future that traditional forecasting techniques are likely to overlook. As futurist Paul Saffo notes: “The goal of forecasting is not to predict the future but to tell you what you need to know to take meaningful action in the present.”\(^{67}\) This white paper provided a general overview of these trends and issues that lie beyond or outside of current performance metrics evaluating the transportation system.

\(^{64}\)Ibid.
\(^{66}\)NCHRP Report 750 Strategic Issues Facing Transportation
\(^{67}\)Paul Saffo, Six Rules for Effective Forecasting, Harvard Business Review, July-August 2007
Next Steps

It is anticipated that the trends and issues identified in this report will be discussed, scrutinized and weighed-in upon by members of the Texas Freight Advisory Committee. The goal of this discussion is to achieve some level of consensus about which trends and issues are likely to have the highest impacts on freight movements in Texas over the next several decades.

The framework for this examination of trends and issue, as noted earlier, is based largely on NCHRP Report 750: Strategic Issues Facing Transportation, which also notes: “By identifying the most significant trends and other forces between now and 2050, considering plausible trend lines (scenarios) for these forces, examining how they might interact with each other, identifying what indicators should be monitored and what the potential tipping points are that would indicate a systematic shift, and determining how the indicators can be monitored, decision makers will be enabled to make better infrastructure investments.”

Creating several trend indicators (potentially as complements to freight performance measures) to track and monitor those trends likely to have the greatest impact on freight in Texas will enable TxDOT to plan and respond more effectively and create a Texas transportation system prepared for the future.