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Seven TxDOT Strategic Research Briefs for FY 2011

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Project 0-6661 TxDOT Strategic Research Program

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Background

The proposed Strategic Research Program (SRP) is intended to prepare the department for the transportation challenges likely to be faced in the next 10–30 years. It complements the current technical research program by addressing longer-term and broader transportation issues that could affect the efficiency of the statewide transportation system.

What the Researchers Did

Eight tasks were completed in the period February 2010 to August 2011. The lead university for each task is indicated in parentheses:

Task 1: Makeup and Role of Oversight Panel/Advisory Committee (TTI): A plan was developed for an oversight panel, ultimately named the **SRP Advisory Committee**.

Task 2: Development of Alternative Project Management Approaches (TTI): An array of options for managing the SRP was developed.

Task 3: Communicating Information (TechMRT): Methods for communicating SRP developments and results were developed.

Task 4: Topic Identification Process (CTR): A preliminary set of broad initial themes for the SRP were developed. Procedures for acquiring, screening, and developing research topics were outlined.

Task 5: Topic Selection Process (CTR): Procedures were laid out for screening and ranking research topics/ideas.

Task 6: Develop "White Paper" Concept (TechMRT): The researchers developed a design for Research Briefs (originally called "white papers"), and prepared one example.

Task 7: Implement the Plan (CTR): The requirements for implementation of the SRP (namely, resources, responsibilities, and timeline) were laid out in a work plan.

Task 8: Development of Research Briefs (CTR/TTI/TechMRT): Seven RBs were developed on topics selected by the TxDOT PMC.

What They Found

External Advisory Committee: Members should be drawn from experts in transportation, major users of the multi-modal system, business executives, and entities who compete for State resources, among others. A list of potential members was submitted to TxDOT for consideration.

Project Management: The recommended key steps in project development are:

1. Gather and screen ideas
2. Select about 10 ideas every 6 months for research briefs
3. Select about 3 research briefs each year for in-depth research projects
4. Disseminate results using latest communication technologies.

Program Communications: All materials and communications will be handled through a dedicated website, initially hosted at http://www.rtfmps.com/.

Strategic Topics: Five themes and 14 sub-themes were recommended for organizing strategic topics:

Theme 1: **Demand**- who will use transportation, where and how.
A. Demographics – the composition and location of population, and required services.
B. Commuting – modes by which people will travel, routes, and volumes.
C. Freight – modes by which goods will move, routes, and volumes.

Theme 2: **Organization**- how the agency responsible for transportation will function.
A. Funding – how the transportation system is paid for.
B. Performance – how the agency provides required services to its customers.
C. Partnerships – how the agency works with others to achieve its goals.

Theme 3: **Infrastructure**- how will the transportation network be engineered and maintained.
A. Engineering – materials and methods for designing and constructing the system.
B. Maintenance – materials and methods for managing the condition of infrastructure.

Theme 4: **Network**- how will system elements connect and operate.
A. Integration – the efficiency of transportation elements in moving people and goods.
B. Safety – minimizing disruption, property damage and loss of lives on the network.
C. Technology – using technology to protect the network and improve efficiency.

Theme 5: **Environment** – how will transportation interact with society and nature.
A. Ecology – minimizing impacts of transportation on natural resources.
B. Lifestyle – enhancing the quality of living, health and prosperity.
C. Challenges – ability to respond to short- and long-term natural phenomena and other challenges.

Research Briefs: RBs will resemble the "Background and Significance" section of RMC proposals, presenting an unbiased look at an issue and possible resolutions.

They should be reader-friendly documents, covering the following:

- What is already known on the topic (literature review)
- What current research is ongoing
- What can be researched (scope of required research)
- Potential applications/benefits (implementability).

Seven research briefs were developed during this project:

1. RB1: "Using Telework and Flexible Work Arrangements as a Congestion Mitigation Strategy"
2. RB2: "The Problem of Congestion and Mass Transit"
3. RB3: "Determining a Comprehensive Freight Strategy for Texas"
4. RB4: "Strategic Directions for Performance Management in TxDOT: Customer Satisfaction as a Key Driver of Success"
5. RB5: "The Future of Texas Freight: Roles, Forces, and Policies"
6. RB6: "An Integrated Approach to the Maintenance and Rehabilitation of Pavements and Bridges"
7. RB7: "The Interstate Shield: Time to Reconsider a Roadway Icon?"

What This Means

Figure 1 is an illustration of the recommended implementation cycle for the SRP.

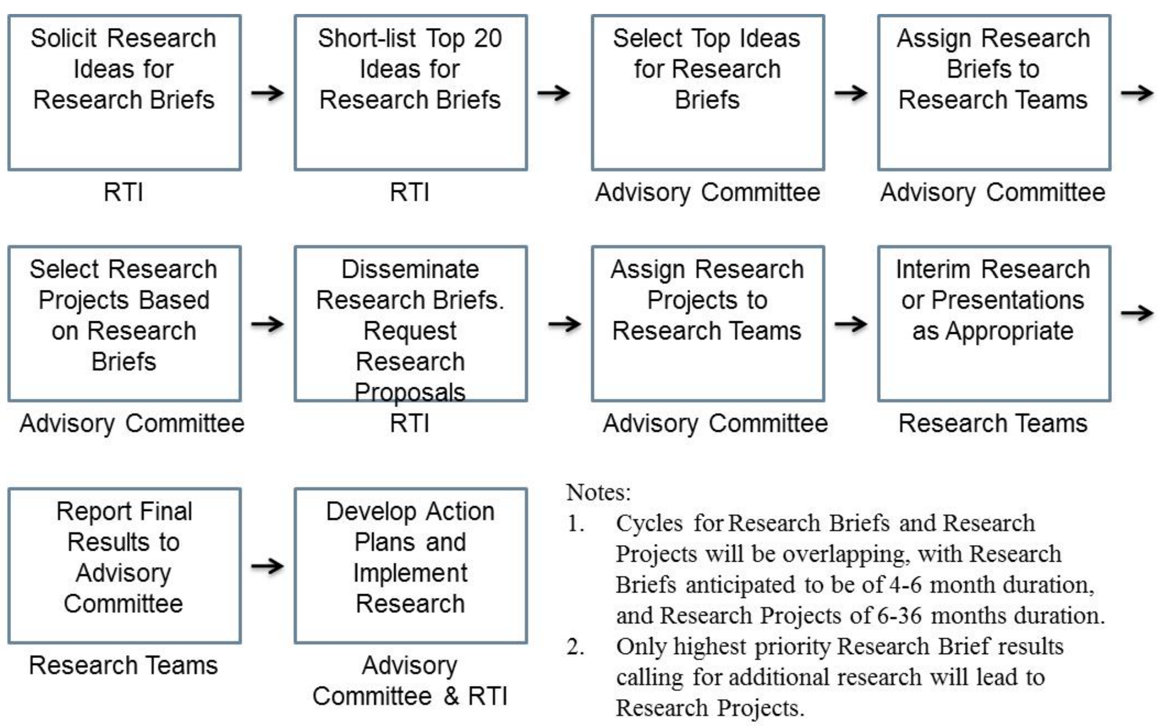

Figure 1: Recommended Implementation Cycle for TxDOT's Strategic Research Program

PREPARED FOR THE TEXAS DEPARTMENT OF TRANSPORTATION

Strategic Research Program: Brief 0-6661

Using Telework and Flexible Work Arrangements as a Congestion Mitigation Strategy

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4/15/2011

Executive Summary

Congestion is one of the most noted frustrations of American citizens today. Urban Texan commuters alone experience an estimated 49 hours of congestion-related delay annually and congestion shows no sign of subsiding in the long run without substantial action. Not only does it affect quality of life and economic competitiveness, congestion can result in reducing travel demand or increasing system capacity or both. This brief will demonstrate that in the current environment of austerity and sharp political tension, it is of critical importance to implement low cost, politically amicable strategies to manage congestion and better utilize system capacity.

Devising a comprehensive plan to handle congestion raises important questions about the very nature of congestion as well as the sustainability and practicability of congestion mitigation strategies. This research brief will propose that publicly promoted flextime, compressed work weeks, and telework (collectively called *flexible work arrangements* in this brief) can offer one of the most cost-effective, readily implementable congestion mitigation strategies available. Such programs have demonstrated success in the private sector and have been successfully repurposed by local departments of transportation to more efficiently utilize the existing transportation network, reduce overhead costs, and save energy.

HR Magazine, a leading academic journal for human resources professionals, describes flextime, compressed work weeks, and telework this way:

- Flextime is a work arrangement with time of arrival and departure that differs from the standard operating hours. For example, a typical flextime arrangement is arrival at 10:00 a.m. and departure at 7:00 p.m.
- A compressed work week allows full-time employees to work longer days for part of the week or pay period in exchange for shorter days or a day off during that same week or pay period.
- Telework, or telecommuting, allows an employee to work at home, on the road, or in a satellite location for all or part of their regular workweek.

Flexible work arrangements have been developed in the private sector as a cost-saving measure and as a reward for exceptional employees. Each program allows workers substantial flexibility in their schedule by adopting new telework technologies or by simply modifying institutional rules. Studies show employees prefer flexibility in their schedules so they can be more productive, strike a better home-work balance, and avoid the costs and stresses associated with a peak hour commute. Employers promote non-traditional work arrangements when they make sense from a business standpoint; companies report reductions in overhead, energy, and paid overtime with non-traditional schedules.

The key difference between flexible work arrangements and other popular demand management strategies, such as tolling and license plate rationing, is that they can be voluntary and still affect the transportation network. The extent to which a program will produce noticeable benefit to the transportation network depends on three characteristics.

- **How we measure and understand social tolerance for congestion.** We know that urban areas are growing and that demand for highway use exceeds capacity in a growing number of places. Drivers who travel on a severly congested freeway either see that facility as the only way of reaching their destination or find the social and real costs of using the faciltiy do not outweight the benefits. A voluntary congestion mitigation strategy has drivers eliminate or shift the time of their trip so that they have a lesser impact on the transportation network. The rate of adoption of flexible work arrangements is unlikely to outpace the growth of congestion, but they can still create measurable benefits to the transportation network. Currently, congestion is usually expressed in terms of cumulative cost or time lost—measures which are difficult to compare and are not necessarily representative of the impact on individual drivers. Successful programs choose to measure their success in number of cars removed from the road each week or day and look to expand that number over time.
- **Participation standards yield higher participation rates**. Not all flexible work arrangements are created equal. Some will benefit employers more than others and it is important that employers find a program that works for them while being held to a standard of participation that will substantially benefit the transportation network. States can make funding or recognition contingent on continued, minimum participation.
- **High-quality implementation support is extremely helpful to employers**. At a minimum, public agencies should provide employers and employees with guidelines,

sample policies, and resources regarding flexible work options. The most-cited reason that flexible work arrangements are left unadopted is resistance by middle management and employees who fear the new schedule will not benefit their career path or job security. High-quality support, funded by state or federal grants, can provide reluctant businesses with human resource professionals who can guide the employer to a strategy that is beneficial for the business and the transportation network. While some employers like IBM, Dell, and the Abilene/Odessa districts of TxDOT decided internally to implement alternative work arrangements without any outside funding, their programs were championed by top-level management who sought cost reductions and improved employee productivity.

Based on the findings of this brief we recommend to TxDOT the following:

- **Further research into the state of flexible work arrangements is not necessary**. The numerous studies by public agencies, private companies, and human resource professionals over the past 30 years have clearly determined the benefits, caveats, and best practices of flexible schedules.
- **Flexible work arrangements should be a part of TxDOT's demand management toolbox because of their high cost effectiveness.** Depending on the program, the cost of implementing a flexible work initiative comes at little to no cost relative to other demand management strategies. There are examples of large, successful demand management programs funded by state and national grants and spurred by increasing investment from the private sector. While flexible work arrangements alone are unlikely to provide sustainable congestion management, their effective implementation can postpone the need for expensive congestion management strategies.
- **TxDOT should take a leadership role in demand management** by coordinating with various public agencies in severely congested urban areas. Because TxDOT is not the only public agency responsible for congestion mitigation, organizing comprehensive demand management strategies among all public agencies will be vital for a successful implementation program.

INTRODUCTION

Traffic is one of the most widely discussed urban issues we face today. At a time when 95% of trips are made in personal vehicles and the average driver spends over 14 hours in congestion each year, traffic is one of America's last shared cultural experiences. Today more than ever, co-workers are more likely to find common ground discussing personal frustration with congestion than any television episode or recently released movie (*1*, *2*).

This paper will argue that in a cash-strapped state with worsening congestion and sharp political tension, it is of critical importance to implement low cost, politically amicable strategies to manage congestion. Flextime, compressed work weeks, and telecommuting are three ideas born in the private sector that have since been adapted by the public sector as a tool for congestion mitigation. Each scheme allows workers substantial flexibility in their schedule by adopting new telework technologies or by simply modifying institutional rules.

Devising a comprehensive plan to manage congestion raises important questions about the very nature of congestion and the sustainability and practicability of potential mitigation strategies. This research brief will also argue that publicly promoted flextime, compressed work weeks, and telecommuting programs (collectively called *flexible work arrangements* in this research brief) can offer one of the most cost-effective, readily implementable congestion mitigation strategies available. *HR Magazine*, a leading academic journal for human resources professionals, describes flextime and telework this way:

- Flextime is a work arrangement with time of arrival and departure that differs from the standard operating hours. For example, a typical flextime arrangement is arrival at 10:00 a.m. and departure at 7:00 p.m. (*3*)
- A compressed work week allows full-time employees to work longer days for part of the week or pay period in exchange for shorter days or a day off during that same week or pay period. (*4*)
- Telework, or telecommuting, allows an employee to work at home, on the road, or in a satellite location for all or part of their regular workweek. (*5*)

The impetus for this paper comes from two related questions posed by the Texas Department of Transportation (TxDOT) Strategic Research Initiative. The initiative developed a series of high-priority research questions after consulting with hundreds of transportation stakeholders, administrators, and academics. Two of the questions are:

1. What measures can be taken to reduce peak hour congestion and more efficiently use system capacity?

2. What can TxDOT do to encourage flex hours, flex days, and telecommuting? Is pricing the answer?

To uncover the answers, this research brief will characterize peak hour travel in order to understand the impact that a commuter-centric congestion mitigation strategy can have on peak travel. A review of congestion mitigation strategies that have been implemented in the United States and abroad will be given with particular emphasis on the theoretical and practical relationship between flexible work arrangements and other congestion mitigation strategies. Finally, case studies of domestic flexible work schedules will be presented with particular focus on those implemented by the public sector.

Current Situation

How We Measure Congestion

The ability to quantify congestion is an important step in developing a congestion mitigation strategy. Because surface transportation projects must be justified before they can move forward, agencies often look to a project's potential to relieve congestion as a primary justification for roadway expansion, signal upgrades, and intersection reconfigurations. Planning alternatives can be compared on their congestion-relieving merits if objective measurements of congestion can be taken and projected under future conditions. Developing measures of congestion is not a difficult task, but this section will argue that congestion metrics, while derived simply, are presented to decision makers and the public in decidedly confusing and unrelatable terms. That habit in turn makes it difficult to evaluate the impact of any congestion mitigation strategy.

The most straight-forward procedure for measuring congestion is to figure how much longer a trip takes during a congested time of day when compared to an identical trip during an uncongested hour. The difference between the two travel times is the delay attributed to congestion. The ratio between the times, called the *travel time index*, can be used to describe congestion severity.

For example, if a trip between a suburban residence and a downtown office takes 25 minutes at midnight and 32 minutes during the morning rush hour, the travel delay attributed to congestion is seven minutes (32 – 25 = 7) and the travel time index is 1.28 (32 / 25 = 1.28). A trip during rush hour takes 28% longer than an uncongested trip.

The delay experienced by a single driver and a corridor's travel time index are transparent measures of congestion and when taken together can provide a fair assessment of a corridor's congestion level. One shortcoming of these measurements is that the number of drivers affected is not revealed. A 10-minute increase in travel time experienced by thousands of drivers should arguably be considered differently than a 10-minute delay experienced by a few hundred, so aggregating the delay experienced by all drivers seems like a reasonable next step in providing a comprehensive picture of congestion. To represent the aggregate effects of travel delay, transportation professionals report congestion in *annual hours of delay* and *annual cost of delay*. Annual hours of delay is calculated by summing the delay experienced by each driver over a particular segment of roadway. TxDOT reports drivers using IH 35 between SH 71 and US 183 suffer a combined 3.9 million hours of delay each year. Said another way, drivers on that 7.2-mile stretch of highway experience a combined 14 months and 19 days of delay in an average 24-hour period.

The annual hours of delay measurement can also be expressed as a cost. If one assigns a value to the time lost in traffic and estimates the cost of operating a vehicle for that additional time, the cost of delay on each traveler can be quantified. Travelers have a personal sense of the value of their time as evidenced by the use of High-Occupancy Toll (HOT) lanes; however, deciding on an average value of time to assign to drivers is a difficult task. TTI's 2009 report assumed a value of "extra travel time" plus additional fuel consumption is $16.01/hour (*9*). TxDOT assumed the combined cost of congestion is $21.75/hour in 2010. When the cost of delay is aggregated across all travelers, the values are astounding. By TxDOT's own measure, the top 10 most congested roadway segments cost Texas drivers over half a *billion* dollars: $525.9 million, to be exact.

When trying to develop a bottom line for congestion, the appeal of aggregate delay and cost is understandable. Decision-makers may feel compelled to invest in surface transportation after hearing that drivers are literally spending years in their vehicles—and that such driving time is valued at billions of dollars–but it is not a relatable way to measure and track congestion. For example, in conjunction with a private-sector human resources firm, the City of Houston launched the "Flex and the City" program, which encouraged all Houston employers to experiment with telecommuting and flexible work arrangements for a 2-week period (*10*). During that time, traffic delays on two stretches of highway would be carefully monitored by the public works department. The mayor's press release announced that the pilot program resulted in a 102-second (or 5.8%) travel time savings for the average traveler—a modest, but measurable reduction[1]. The release later went on to say that the combined savings would amount to $16.8 million in productivity, fuel, and accident avoidance over one year. The release estimated that over 16,000 hours (about 22 months) could be saved each year. If anything, this demonstrates how divergent driver-specific and aggregate representations of congestion can appear.

In light of these issues and in an attempt to present a clear, comprehensive description of congestion, this brief will express congestion in the following ways when discussing congestion mitigation strategies:

- Number of cars removed from the road
- Reduction in vehicle-miles traveled (VMT)
- Time savings experienced by each driver

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[1] According to the release, 68% of drivers sampled reported that their comute was "faster or much faster" than usual. Note that the travel time savings were only measured for the two pre-designated stretches of highway whereas the question was posed about the driver's entire commute.

Congestion Yesterday, Congestion Today

Congestion is widely cited as one of the most pressing transportation issues facing the United States today (*11*, *12*). Often described in the media as a modern, auto-centric problem, congestion is rarely considered in a historical or social context. In fact, prosperous societies throughout history struggled to solve the congestion issues of their time and acknowledged the real and social costs it placed on society (*13*). In Ancient Rome, Julius Caesar restricted carriage travel within the city walls to relieve overcrowded streets. In 1660 King Charles II of England issued a proclamation, lamenting that congestion in London had

> *"the streets made…unpassable, the pavements broken up, and the common passages obstructed and become dangerous, our peace violated, and sundry other mischiefs and evils occasioned" (14).*

In response to the frustration of his subjects, King Charles declared that carriages were prohibited from standing in the streets while waiting for passengers, but instead had to wait in stables or yards (*14*). By the 1840s, Londoners were counting traffic volumes at intersections and Parliament had established a number of committees charged with addressing congestion (*13*). Within the last century, the advent of the automobile and widespread implementation of public transportation systems created careers for transportation and traffic planners who strive to make surface transportation efficient in the face of growing demand.

While congestion is a measurable, unavoidable consequence of sharing the road, how drivers perceive that congestion is a matter of personal and social perspective. For instance, a 30-mph commute on a congested freeway that was designed for 60-mph traffic can be quantified as a congestion problem, but it may not be considered unacceptable to the average driver. In fact, studies have shown that the average commuter prefers a 20-minute travel time and that driving can serve as a much-needed "buffer" between work and home.

PROBLEM DEVELOPMENT

Characterizing Peak Travel

The impacts of congestion reach beyond slowing the movement of automobiles and trucks. Congestion impacts economic competitiveness, wastes finite resources, impacts quality of life, creates environmental problems, and can affect other modes of transportation (17). Studies by public and private agencies have shown that the intensity, extent, and duration of automobile congestion in the United States has worsened over the last 25 years and shows no sign of abating in the long run without substantial recourse (7, 18).

Across America and in Texas, drivers are spending additional time and fuel on each trip as a result of growing congestion. Attempts to measure the impact of congestion in the U.S. estimate that over $87 billion and over 3.7 billion hours are lost annually to congestion in urban areas (*7*). TxDOT estimates that each urban commuter in the state experiences an average of 49 hours of congestion-related delay annually (*19*) and that congestion levies an additional cost between $161 and $1,112 per year[2] on each commuter (*20*). The impact of congestion has begun to reach more than the commuting population. In 2006 it was estimated that highway congestion impacted 67% of all travel and was responsible for extending the time spent in by all peak-hour travelers by 37%. By TxDOT's estimate, congestion costs Texans a total of $6.8 billion annually (*21*).

When looking at congestion from the standpoint of congestion mitigation, there are a few important questions. This section will try to answer:

1. **Where is everyone going during the peak period?** Are the cars on highways during the morning peak period all headed to work or somewhere else? Are there different profiles in the morning and afternoon?

2. **How are those trips being made?** Do certain trips gravitate to highways? What kind of impact on highway congestion can a congestion mitigation strategy expect to return?

3. **How can that information be used to design an effective congestion mitigation strategy?** How can resources be used most efficiently?

The most severe automobile congestion is experienced during the weekday morning and afternoon peak periods, which are typically defined between 6:00 a.m. and 9:00 a.m. and 4:00 p.m. and 7:00 p.m. in transportation literature. Interestingly, the purpose of peak hour travel is not confined to work- and school-related trips. To try and answer the question "Where is everyone going during the peak period?" consider this data from the 2001 National Household Travel Survey (NHTS). The study found that trips directly related to school or work made up 76% of AM peak trips and 45% of PM peak trips, suggesting that a substantial amount of peak period travel is discretionary (*18*). A more detailed look at morning and afternoon peak travel is shown in Figure 1.

[2] The 2007 estimates by TTI place the cost of congestion on each commuter in terms of additional operational costs and value of lost time at the following amounts: Brownsville $161; Corpus Christi $180; Beaumont $228; Laredo $306; El Paso $382; San Antonio $765; Austin $812; Dallas $1,077; Houston $1,112.

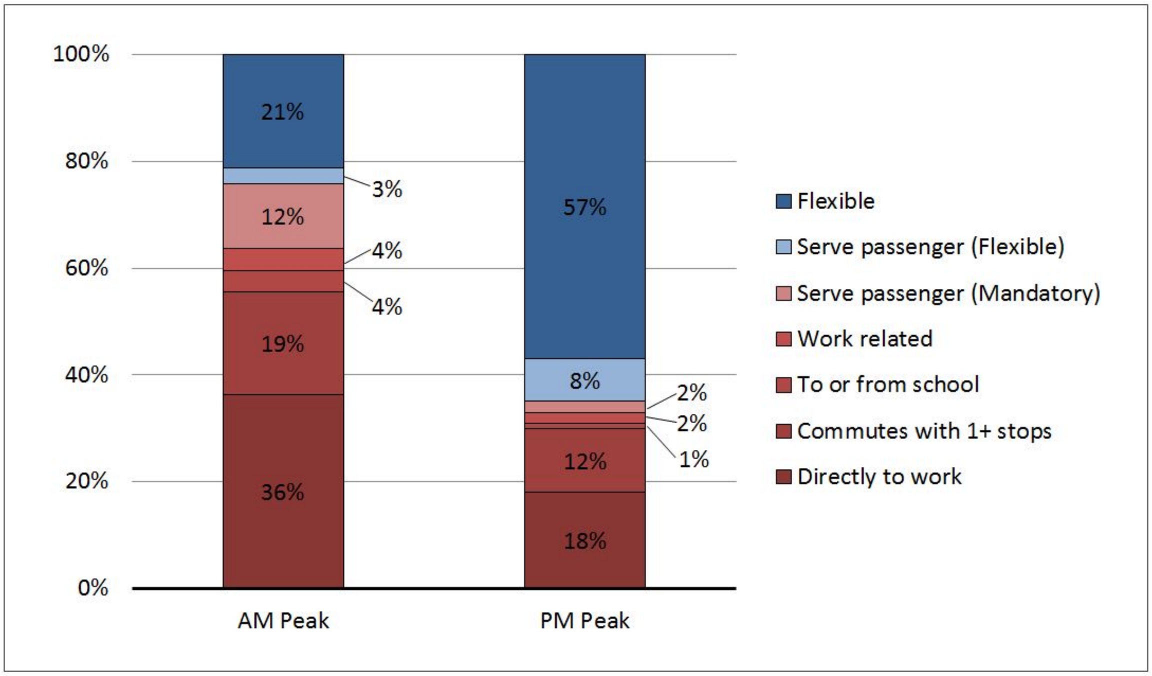

Figure 1. Characteristics of AM and PM peak travel from 2001 NHTS

The NHTS does not ask respondents to identify trips as discretionary or otherwise, instead the referenced study classified work and school related trips as "mandatory" and all other trips as "flexible." Without this piece of information, it is difficult to determine the proportion of peak-hour trips are flexible—those trips for which the departure time or destination can be changed. One can imagine that certain medical trips, shopping trips, or personal meetings are often more flexible than arrival times at work or school.

The data shown in Figure tells an important story about the expected impact of a congestion mitigation strategy aimed at work-related trips. For example, consider a hypothetical initiative that gets 5% of all commuters to telecommute every day. The impact on the transportation network during the morning peak will not be a 5% reduction in traffic volume. Instead, one could expect a 5% reduction in the proportion of commuters who are traveling directly to work and a reduction of less than 5% among those who make one or more stops during the morning commute—imagine some of those stops are errands that cannot be performed at another time, so the traveler will probably still make the trip. Combine these reductions and one could expect about a 2.6% reduction in overall morning peak travel. Because mandatory, work-related trips make up a smaller proportion of afternoon peak travel, one could expect about a 1.5% reduction in travel.[3]

According to the 2009 NHTS data, 80% of home-based work trips (HB-Work) are made using an interstate among travelers who used an interstate for at least one other trip during the survey period. This information suggests that in designing an effective congestion mitigation strategy, it would be advantageous to target highway-adjacent places of employment. Without a targeted strategy, there would be wasted time, resources, and manpower on the order of 20% as commuters who do not use highways adopt flexible work arrangements that do not directly affect highway congestion.

Figure 2 shows both the proportion of home-based work trips and the total number of daily trips. For clarifying purposes, the peak periods are shaded. Notice that the proportion of home-based work trips made via the interstate is relatively stable at 80% during both peak periods.

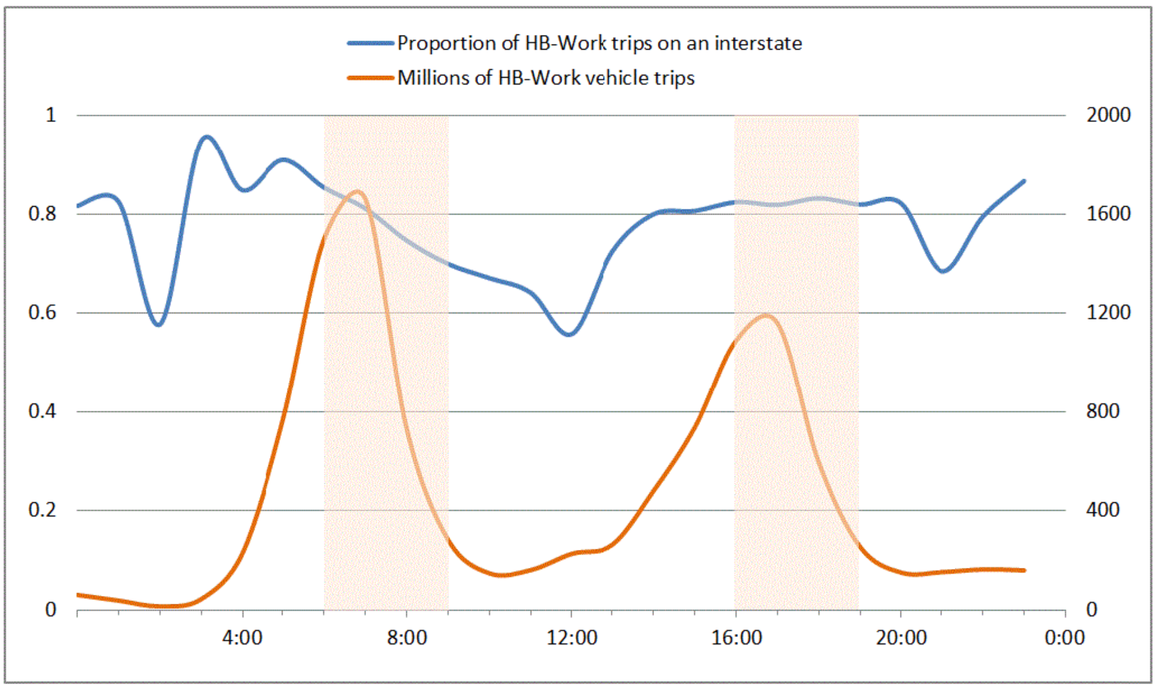

Figure 2. Characteristics of home-based work trips

This look into the nature of peak travel suggests a few ways to design an effective congestion mitigation strategy. Perhaps the two most important things to consider are:

[3] This figure was calculated by assuming that 5% of "directly to work" trips would be removed and 4% of "commutes with 1+ stop" would be removed.

- **Target highways.** Urban freeways are the most congested roadways in Texas, so efforts that remove cars from highways will be the most effective. Because 20% of home-based work trips (among interstate users) do not use interstates, blanket initiatives will waste resources on travelers who do not contribute directly to the most-congested roadways.
- **Expect small returns.** Commuters aren't the only people on the road. About one in four morning peak travelers and nearly two in three afternoon peak travelers are making non-mandatory trips. A program that makes substantial headway in modifying the travel behavior of commuters will still be subject to erosion by the prevalence of non-commuters.

SOLUTIONS AND BENEFITS

Several strategies to manage peak hour congestion have been put forth by the public sector, elected officials, the media, and independent think-tanks. Proponents of congestion mitigation strategies cite potential economic, environmental, and quality of life benefits. Usually, the proposed solutions either seek to reduce congestion with a major compulsory initiative like ubiquitous user-fees or look to encourage more favorable commuting behaviors with voluntary measures along the lines of carpooling or taking transit. This section will explore three broad categories of congestion mitigation strategies: compulsory, incidental, and voluntary.

Compulsory Congestion Mitigation Strategies

Compulsory strategies seek to control demand for roadway use by subjecting each driver to a set of rules or disincentives. Two popular strategies, license plate rationing and roadway pricing, are considered compulsory strategies in this section because the plan is designed to affect the vast majority of road users.

License Plate Rationing

License plate rationing is currently used to manage traffic in Mexico City, Bogota, and Sau Paulo. Fundamentally, license plate rationing seeks to reduce automobile use by banning vehicles with particular license plates from driving on certain roadways or during certain times of day. In theory, license plate rationing would affect all road users equally and would not place an inequitable burden on poorer households.

In November 1989, Mexico City implemented a program that restricted license plate numbers ending in either of two particular digits from driving within downtown during business hours on one weekday (for example, plates ending with a 5 or 6 could not enter the city on Mondays). In theory, *Hoy No Circula* (No Circulating Day or HNC) would reduce traffic by 20% on weekdays as one-fifth of vehicles would be restricted from driving downtown on work days. During the trial period, Mexico City saw a reduction in daily vehicles by 20% and subway ridership increase by 7%. However, drivers adopted new behaviors to avoid the license plate restrictions, ultimately diluting the effectiveness of the program.

An examination of the long-term effects found weaker results, particularly a 7.6% reduction in weekday traffic volume and no evidence of sustained increase in transit use. The program's effectiveness was damaged after single-car households purchased an additional vehicle to avoid the restrictions and still more commuters ultimately opted to use taxis instead of the subway. As a result, fuel consumption per capita increased after the program was implemented and it was noted that air quality did not improve (*22*). Mexico City intended for the HNC to reduce pollution, but detailed studies found "no evidence of long-term improvements in air quality" and even found a relative increase in air pollution during weekends and times when the restrictions did not apply (*22*).

Pricing Schemes: Sustainable Congestion Management

Perhaps the most pervasive idea is that of pricing. Proponents of pricing rightly point out that a well-established price can dramatically reduce automobile congestion and generate revenue. It has been demonstrated that an effective pricing scheme can significantly increase automobile speeds and guarantee drivers a congestion-free trip. Examples of the current best practice in pricing come from overseas. London charges drivers a hefty fee for entering downtown during weekday business hours and Stockholm charges[4] automobiles for driving on highways near the central business district. Both cities have seen traffic volumes reduced by about 15% and traffic delays reduced by up to 30% (*23*, *24*). A variable electronic tolling system on Singapore's highways can charge automobiles different fees depending on the current demand for a facility to avoid the event that demand exceeds capacity. Singapore reduced traffic by 13% and drivers have experienced a 22% faster trip since the program was upgraded in 1998 (*11*). While these are notable, well-documented examples of successful pricing systems, the implementation of similar pricing systems has often proved politically unpalatable in the United States due to lack of public consensus and the various equity issues it raises (*25*).

Pricing strategies as congestion reduction measures are likely to be met with great political resistance, but pricing offers the only sustainable demand management solution. As described in a 2004 study by the RAND group, any attempts to remove cars from a roadway will be offset by latent demand for that facility in the long term.

> *"[It has been] noted that many people already make a conscious decision to travel at other times of day, on different routes, or by different modes—*

[4] Effective January 4, 2011, London charges between £9 and £12 ($14.28 and $19.04) to enter the downtown cordon zone between 7:00 a.m. and 6:00 p.m. on weekdays. Stockholm charges bewteen kr10 and kr20 ($1.49 and $2.99) to utilize toll roads near downtown; a day's charges cannot exceed kr60 ($8.96). Currency equivalents were taken from the exchange rates published via Google Finance on January 14, 2011.

> *even if this involves some inconvenience—so as to avoid congested travel conditions. If strategies are employed to improve the flow of traffic on crowded thoroughfares, however, travelers will soon notice the reduction in congestion and return to their preferred travel patterns. In other words, there will be a triple convergence on the newly freed capacity—as travelers shift from other times of day, from other routes, or from other modes—thus eroding the initial peak-hour congestion reduction effects. Over the longer term, general increases in automotive travel demand resulting from economic expansion and population growth will further undermine the effectiveness of many strategies." (17)*

While pricing schemes can create sustainable benefits for the environment, congestion, and fuel use, the idea is unpopular because it is viewed as unfair. Toll lanes have been dubbed *Lexus Lanes* as they are perceived as "an unfair way for wealthy drivers to buy their way out of congestion, leaving the less well-to-do stuck in [traffic]." Cordon zones raise fears among residents living on the zone's fringe (who fear their streets will become parking lots for commuters to avoid the cordon fee) and long-distance commuters are effectively paying for improvements to another city's transportation infrastructure. When compared to other congestion mitigation strategies, pricing requires huge political capital investments in addition to the up-front infrastructure costs to collect the user fees. Without favorable budget conditions and a high-profile champion, it is imprudent to turn to pricing schemes to widely manage congestion (TRB 10-4016).

Incidental Congestion Mitigation

The severity of congestion in urban areas is often tied to economic conditions and fuel prices. During economic downturns, higher unemployment can result in fewer cars on the road and travel delays can be significantly reduced, as occurred during the first year of the recession that began in late 2007. From December 2007 to December 2008 increased unemployment caused weekday traffic volumes to drop between 2% and 4% and travel delays were cut by 3% to 5% (*7*). Fuel prices can have a marginal impact on travel patterns as well. As gasoline prices rose to above $4.00 per gallon in the summer of 2008, national gasoline consumption decreased by 0.4% in 2007 and by a further 0.5% in the first two months of 2008. Gas prices and the economy are often in a state of flux, so incidental congestion reduction is a temporary relief. One can assume that old travel habits will return once the economy picks up or gas prices fall again.

In a stagnant economy with perpetually high fuel prices, it is unlikely that congestion will disappear. A person who struggles to afford gasoline or maintain their vehicle will adopt cheaper travel behaviors like trip-chaining, carpooling, or acquiring a cheaper or more fuel-efficient vehicle. While overall VMT will decrease as a result of these new behaviors, it is not likely that congestion will fall to a level where one can move freely by car during peak periods. Incidental congestion reduction is not permanent and therefore should not be viewed as a congestion-mitigation strategy. Rather, it should be viewed as a driver of the behaviors that affect automobile traffic and controlled for when evaluating the impact of congestion mitigation strategies.

Voluntary Strategies to Congestion Mitigation

Voluntary congestion mitigation strategies seek to reduce congestion by providing road users with more options regarding the time and nature of their commute. Such strategies are likely to gain political and public approval because they provide participants with increased autonomy and do not disincentivize non-participants. Therefore, public agencies seeking consensus on congestion mitigation measures often implement voluntary programs like flexible work schedules and telecommuting (*17*).

Voluntary programs can be most effectively implemented in areas where work-driven, peak-hour congestion levels are particularly severe and concentrated. Although each is slightly different, the voluntary programs challenge the institutional rules that demand a traditional workday and encourage automobile commuters to shift their peak period trips to off-peak hours or to remove trips entirely[5].

Unlike many other congestion solutions, there are no direct costs to a public agency to maintain a flex time, flex day, or telecommuting program within the community it serves. Costs are largely the product of providing consultants to describe, organize, and implement such programs for the participating employers.

Flexible work arrangements offer employees some freedom to choose when and how they work and—by extension—how they contribute to congestion. Individuals who take full advantage of flexible work arrangements rarely work a traditional five-day, 9:00 a.m. to 5:00 p.m. workweek. Employees may start work later or earlier than normal, work longer days to earn an extra day off, or utilize technology to work from outside the office. Regardless of the flexible work arrangement chosen, there is a countable benefit to the transportation network as trips once taken during the peak period are shifted to less congested times or eliminated. This chapter will discuss the characteristics of flextime, compressed schedules, and telework.

Flextime

Flextime is a work arrangement that lets employees choose atypical times of arrival and departure. For example, a flextime worker might arrive at 10 a.m. and depart at 7 p.m. one day and work from 6:30 a.m. to 2:30 p.m. the next. Employees who take advantage

[5] The role of public transportation in reducing congestion is the subject of a separate research brief commissioned under Project 0-6661 TxDOT Strategic Research Program. As such, the authors acknowledge the critical role public transportation can play in a comprehensive congestion mitigation strategy. In order to avoid duplicating the efforts of the other research team, the authors of this brief will not expand on the role of public transportation.

of flexible schedules have the ability to choose to travel at less-congested times of day and therefore allow the transportation network to be utilized more efficiently.

In practice, flextime poses some problems that employers and employees must work out to ensure a mutually beneficial policy. Some of the most-cited concerns are:

- How can the employer ensure that at least some employees are on-site during normal business hours?
- How does an employer exercise employee oversight and host team meetings if work schedules are not fixed?

To the first question, employers can enact a policy that requires that employees announce when they plan on arriving each day. Such a policy gives employers greater control over scheduling to ensure that adequate manpower is available during normal business hours. Employers are often reluctant to enact any flexible work arrangement because it reduces their ability to oversee day-to-day operations. In a good flextime schedule, employers can choose to deny flextime benefits to employees with a poor work record—allowing them to retain oversight over troublesome employees and to make flextime a benefit to be earned. In many flexible work arrangements, employers define “core hours” or times of day during which all employees must be present so that meetings can be held and housekeeping matters can be addressed. Typical core hours are set up during the middle of the day, such as from 10:00 a.m. to 2:00 p.m.

Compressed Work Week

A compressed work week is one of the most popular flexible work arrangements because of its simplicity, potential cost savings, and appeal to employees. Workers on a compressed work week might work 10-hour days Monday through Thursday and take Friday off or work -9hour days and take 1 day off every other week (*4*). If an employer extends compressed work weeks as an optional benefit to employees, the policy closely resembles flextime—employees can compress their hours so that they can take a day off. However, when enacted as a mandatory change in operating hours, compressed work weeks can provide significant cost savings and efficiency improvements while raising unique human resource concerns.

The benefits of compressed work weeks stem from (1) the lengthened work day and (2) the day off. Because the work day is extended, jobs that require big start-up and shut-down times can greatly benefit. Consider a manufacturing plant with machinery that takes an hour to turn on and an hour to turn off. In an 8-hour work day, 25% of time is utilized waiting on the machinery. Add in a 1-hour lunch break and now only 5 hours of the day are used for production. TxDOT’s Abilene and Odessa districts essentially recognized this efficiency problem with their maintenance crews who spend a lot of time setting and removing traffic controls at work sites. The switch to 10-hour days substantially increased productivity. (See TxDOT Compressed Work Week in the following chapter.)

Jobs with compressed work weeks can see significant reductions in operating expenses and overhead costs by removing one day from the work week. The TxDOT experiment in Odessa saw fuel, water, and repair costs drop under the 4-day system and Utah saw utility costs drop by about 13% since most state employees started skipping Fridays.

With compressed work weeks, most complaints center around the logistical problems and fatigue associated with a lengthened work day. A longer day at the office can mean trouble for parents with school children. An early start time makes it difficult to get your child ready for school and a staying later means arranging childcare until 6:00 p.m. or later. About 20% of Utah's state employees struggle with their 4-days-a-week schedule. Unfortunately, few remedies exist for these problems, as they stem from the very nature of a compressed work week. It is possible for managers to use some of the cost savings to provide reduced-cost child care for employees with young children or to offer employees with ways to de-stress during the long work days.

Telework

Telework, or telecommuting, is a relatively modern work arrangement that gives an employee the option to complete some or all of his work away from the office and outside of typical business hours via an electronic connection. Like compressed workweeks and flextime, businesses adopt telecommuting policies to both reward employees with additional flexibility and to lower operating costs. Because of its broad definition, many work behaviors can be classified as telework. The following activities would, under most definitions, qualify as telework.

- An advertising professional could produce content from home using his personal computer and correspond with clients using his home phone. He may rarely, if ever, visit the office.
- An engineer could send e-mails from home until 10:00 a.m. and then visit the office for collaboration and more intensive work.
- A corporate executive could host a conference call with managers at a nearby branch from his work office to avoid making the trip by car.

Telecommuting remains a little-used work arrangement despite expectations that it would come to define modern work-life balance. From a transportation perspective, telework allows participants to take fewer work-related trips—or at least fewer trips during peak hours—thereby removing some mandatory, work-related trips from the road (*5*) (*31*). Employers are not necessarily looking at telecommuting to reduce congestion; they want to be more efficient in the way they do business (*32*) (*33*).

Telecommuting as a Prisoner's Dilemma

Technological advances over the past 20 years have made telework a more viable work arrangement, but it is far from the dominant workplace option it was expected to become. In 2001 somewhere between 9 and 24 million Americans telecommuted regularly—far below the 55 million that was predicted. That same year, another report found that while a majority of Fortune 1000 companies offer telecommuting, most have report participation rates below 5% (*34*) (*35*). This might imply that telecommuting is an undesirable work arrangement, but in fact the opposite seems to be true. Best Buy, American Express, and Dow Chemical have fully embraced telework and report that teleworkers are 35–43% more productive than traditional office workers (*36*). When asked, most employees say they would like the option to telecommute; they anticipate improved productivity, a better work-life balance, and saved travel time. This brings forward another question: If so many companies offer telecommuting options and so many employees want to telecommute and so many working-class Americans have a high-speed internet connection[6] from home (*37*), why aren't more people telecommuting?

The answer seems to lie in the perceived consequences of telecommuting or allowing your employees to telecommute. Many actors in the workplace are unsure if telework will ultimately benefit their professional development and job security. One human resource professional summarized the feelings of many managers in this way:

> *The biggest barrier to telework is resistance by middle management… If Big Bob looks out over his Dilbertville and doesn't see cubicles filled with busy workers, he's going to wonder and feel uncomfortable about what he's paying [middle management] to do* (*34*).

Sarcastic as it is, this point of view appears to be widespread. According to the Federal Highway Administration (FHWA), the biggest barrier to implementation of telecommuting is "the mistrust of supervisors or misunderstood rules or expectations on the part of employees" (*38*). One study cites 75% of managers involved in a telework arrangement "can trust their employees, but a third say they would like to be able to see them, just to be sure (*35*)."

Middle managers think their job will be at jeopardy if they do not have employees to physically oversee each day and those employees feel their work ethic and quality will go unnoticed unless they are seen putting in time at the office each day. This standoff between management and employees is a classic prisoner's dilemma. If only one party chooses to telework, that party risks an unfavorable situation, but if both agree to telecommute, both parties can reap greater benefits. Both parties must set a series of ground rules and write effective telecommuting policy. When transitioning to telecommuting, human resource professionals recommend the following remedies.

[6] The 2011 US Department of Commerce report cited here found that 73% of employed persons in the United States have a broadband internet connection at home.

- **Determine which jobs are ready for telecommuting.** Jobs with measurable products, deliverables, or specific due dates are the best fit for telework because an employee's progress and output can be easily measured on a regular basis (*39*).
- **Offer guidance detailing which employees should be allowed to telecommute.** Some companies screen employees and only allow the most effective to telecommute.
- **Provide training to management.** This helps prepare managers for the switch and gives them the proper tools to ensure a successful transition.
- **Establish written program guidelines.** Designate which jobs are eligible for telecommuting, explain that managers and employees can collaborate to ensure a mutually beneficial arrangement, and allow the telework arrangement to be terminated if performance suffers.

One final concern is that of security. When sharing documents, emails, and information online, there is a always the risk that sensitive data is intercepted by a third party. Often times a teleworker will use their personal computer to access his employer's servers. If the home computer is not secured well, the entire database could be at risk. Fortunately, secure connections can easily be established through virtual private networks (VPN) or other relatively inexpensive technologies (*40*). Other businesses simply provide all teleworkers with company-issued computers to ensure a safe connection (*33*).

Telework and Transportation

If done correctly, flextime, compressed workweeks, and telecommuting can be extremely effective business tools, but their effect on congestion is still an unanswered question. When studying flexible work arrangements from a transportation standpoint, "the crucial component of [flexible work arrangements] is the elimination, or partial elimination, of a commute trip (*31*)."

Research has confirmed the theory that the average teleworker will consume less fuel and travel fewer miles, thereby reducing demand on the transportation network. As mentioned previously, telework can include foregoing a trip to work altogether or traveling outside of the traditional peak period. To make a noticeable impact on congestion though, a substantial portion of the commuting population would need to shift their trips to avoid traveling during the peak hour.

SPECIFIC SOLUTIONS

This section chronicles the successes and failures of notable public and private sector telecommuting, flex time, and flex day initiatives. A wide range of programs have been implemented across the country with a variety of travel options, costs, benefits, and effectiveness. The best practices from each program are explained in order to build a successful program for TxDOT. Following is a summary of case studies.

EWorkplace (Minnesota)

Quick Summary

Minnesota's application for federal money under the Urban Partnership Agreement included a proposal to implement telecommuting as a congestion mitigation strategy. Federal and state money paid for eWorkplace, a program that provides human resource consultants to companies that are interested in significantly reducing trips to work. The program includes 40 employers, 3,000 regularly participating employees, and significant cost savings for those participating employers in foregone travel expenses. It represents one of the most intense, successful, and expensive publicly promoted flexible work arrangement programs.

Impetus

In 2006 the United States Department of Transportation announced its Congestion Initiative, which outlined strategies to tackle congestion on the nation's roads, rails, runways, and waterways. One major component of the initiative was the Urban Partnership Agreement (UPA), a program that would provide funding to metropolitan that promised to implement programs with "a combined track record of effectiveness in reducing traffic congestion (*45*)." Minnesota's application included investments in "technology, transit, and telework" and was awarded $133 million from the UPA (*46*). The state legislature provided $50.2 million in additional funds during the 2008 legislative session, $3.2 million of which was used to create eWorkplace, which would promote the "telework" part of Minnesota's congestion mitigation strategy. EWorkplace's stated goal is to "reduce congestion in and around the Twin Cities by encouraging employers to offer employees the option to telework (*47*)."

Implementation

EWorkplace launched in early 2009 as a joint effort by the Minnesota DOT and the Hubert Humphrey Institute of Public Affairs at the University of Minnesota. The program seeks out employers who are willing to commit to one of two trip-reduction programs.

The first is a traditional telework program administered by MetroTransit and a coalition of Minneapolis-St. Paul Traffic Management Organizations. Employers who join the program must commit a minimum number of employees to telework at least 1 day per week for at least 3 months. To qualify, employers must have an address within the seven-county area surrounding the Twin Cities (*48*). In exchange for joining the program, employers receive access to consultants who advise the company on how to best establish flexible work arrangements and gain access to online tools to track the travel reduction impacts of their telework program. Other incentives include a free 3-month subscription to popular telework software packages (*48*) and special mention in eWorkplace publications (*47*).

The second program requires a “dramatic cultural shift” to the Results-Only Work Environment (ROWE). ROWE is a unique workplace culture created by CultureRx, a private human resources company that promotes work arrangements that focus exclusively on the accomplishment of pre-established benchmarks. Participating employees are never required to visit the office if their work can be accomplished elsewhere. This significantly cuts down on travel and provides the employee with maximum flexibility in determining their work-life balance. While a ROWE is not an effective work arrangement for all employers, two eWorkplace participants have established a ROWE and reported positive results.

Results

Based on the data collected by eWorkplace participants, the average participating employee saves $1,300 per year in foregone business travel[7]. The program has enrolled 40 employers as of January 2011 and 3,000 employees participate in the program. EWorkplace estimates that participants saved a total of $3.9 million after one year in the program, resulting in a return on investment of 1.2. As of January 2011, over 93% of employers surveyed planned to continue participating in eWorkplace and about two-thirds planned to extend telework options to more employees (*49*).

In an eWorkplace survey, participating employers cited increased productivity, morale, and improved customer service after implementing the program. According to an internal MnDOT survey, participating MnDOT employees reported decreased stress levels and reduced absenteeism. Fairview Health Services, a private medical clinic, reported a 50% reduction in overtime hours logged by program participants (*47*).

Best Practices

EWorkplace should be considered a best-practice example of voluntary congestion mitigation because of the high expectations and high return to the employer, participating employees, and the Twin Cities.

Commute Trip Reduction (Washington State)

The Commute Trip Reduction (CTR) program requires that all employers in the state of Washington with over 100 employees traveling to a single worksite between 6:00 and 9:00 a.m. implement one or several trip reduction strategies. Funds are distributed from the state to local jurisdictions that provide tailored information on CTR strategies to local employers.

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[7] This figure was estimated by multiplying the number of travel miles reduced by a value of 50 cents per mile. That figure was taken from the United States Internal Revenue Service, which used 50 cents per mile as the value for calculating tax deductions related to business travel in 2010 (*30*).

Impetus

In 2006, the Washington State Legislature passed the Commute Trip Reduction Efficiency Act to require that local governments in highly congested areas "develop and implement plans to reduce drive-alone trips and vehicle miles traveled per capita (*46*)." Under legislative mandate, the Washington State Department of Transportation (WSDOT) chose to expand and improve the CTR program initially developed in 1991. The new CTR would allow local jurisdictions to implement ad-hoc trip reduction programs in major employment and residential centers located near congested corridors, and make the CTR governing board more policy-oriented (*47*).

The program planned to reduce drive-alone commute trips to CTR worksites by 10% and cut VMT by 13% before 2011. WSDOT estimated that these goals, if realized, would move the state closer to achieving its greenhouse gas reduction objectives and maintain traffic volume at the 2007 level without discouraging jobs or residents from entering the area (*47*).

Implementation

CTR is a partnership among governments, employers, and citizens across the State of Washington that encourages commuters and residents in congested urban areas to ride the bus, carpool, walk, bike, telecommute, or compress their workweek. Compared with other state-lead initiatives, CTR is unique in that it requires businesses with 100 or more full time employees at a single site whose workday starts between 6:00 and 9:00 a.m. to implement a trip-reduction program. In order to meet CTR requirements, an employer can choose which alternatives work best for their individual business. In other words, large employers must participate in the program, but their level of participation is discretionary. Local governments provide technical support and services to help employers choose and launch CTR programs to achieve their trip reduction goals. For example, the high-tech manufacturing firm Hewlett-Packard offers telework to most of their employees, while Macy's, a national retailer, has had more success with flexible schedules and compressed workweeks (see the Commuter Challenge case studies [51]). Although they are not required to do so, smaller businesses are encouraged to implement trip reduction programs that work best for them (*48*).

The program is funded partially by state grants. For example, the Kitsap Regional Coordinating Council (a coalition of Kitsap County's local governments) received $150,000 from the Legislature to develop and implement a telework program for Kitsap employers. The project provided employers in Kitsap County with a telework toolkit, a work template, and guidance to promote telework. However, a lot of investment comes from participating employers as they invest and expand their own commute reduction programs. In 2004, before the legislative mandate to expand CTR, employers invested $49.4 million into CTR programs, over $18 for each dollar invested by the state (*49*). Once employers discover that CTR programs make sound business sense, they further fund the strategy to further increase productivity, efficiency, and employee morale.

CTR is coordinated by WSDOT, which determines the program's policy, evaluation measures, and allocates state grants to local jurisdictions. When it comes to in-house expenses, Keith Cotton, the Urban Programs Manager for WSDOT, does not associate any direct costs with flexible schedules, compressed workweeks, and telecommuting, but rather "soft" costs that result from an employee being absent from the office. Soft costs include additional online correspondence, providing instructions and work schedules for teleworkers, and monitoring production of off-site employees (*50*).

A legislative mandate requires that CTR be evaluated every two years. Each CTR worksite is required to survey its employees and report the commuting habits of its employees. Information about mode share, frequency of work trips, and distance traveled are the most important pieces of information. That data can then be used to determine shifts in mode and changes in VMT per employee. By requiring a state-wide evaluation of CTR worksites, WSDOT can track how well each demand management strategy is performing and make strategic evaluations about which direction to go in the future. This accountability has proven to an important staying power of the program, as WSDOT must disclose CTR's effectiveness in specific terms (*50*).

Results

Currently, over 1,000 worksites and roughly 530,000 employees have access to CTR programs statewide. WSDOT reports that 28,000 fewer vehicle trips were made each weekday morning in 2009, providing relief to some major traffic chokepoints (*49*). As a part of the 2009 evaluation, WSDOT used a traffic simulator to estimate the severity of congestion in the Puget Sound Region (which includes Seattle, Tacoma, Olympia, and Everett) under the hypothetical condition that all CTR commuters returned to drive-alone trips at the rate they did before entering the program. A 7.6% reduction in delay was computed, which corresponded to $59 in savings per morning commuter due to reductions in fuel use and travel time. The delay for the region for 2009–2011 is estimated to be $99 million worse if CTR was eliminated. Considering the state's $2.8 million annual investment in that region, the state is getting a 35-to-1 return on investment[8] (*49*). Further, the reduction of 62 million VMT by participants saved an estimated $7.8 million in fuel costs and reduced greenhouse gases by 27,460 metric tons statewide. Lastly, in a survey of 1000 CTR worksites, slightly over 3% telecommuted on a regular basis (*46*).

In 2009, the Government Management Accountability and Performance, a division of WSDOT, formed a report measuring the effectiveness of their internal CTR program. According to the report, 63% of the total WSDOT workforce worked on a schedule other

[8] It is important to note that the impacts of the program today are built off previous investments in CTR. The ROI estimate does not mean to imply either that failing to fund the program will eliminate all the benefits, nor that if the investment were doubled, the benefits would also double.

than the traditional 8 hours per day, 5 days per week. Over half of the employees have changed their schedule to eliminate two or more trips into work each month. About one-third of the WSDOT staff participates in a CTR program that reduces travel to the office between 6:00 and 9:00 a.m. (*50*).

Best Practices and Take Aways

As a whole, the CTR program is highly accepted for public and private agencies alike in the State of Washington. Its mandatory-but-flexible structure and its impressive (if short) track record should qualify it as an example of best practice in implementing a publicly sponsored trip reduction program. Two aspects of the program stand out as critical elements. First, all large employers are required to implement CTR strategies but they are given the choice of which strategies to actually adopt. Because employers must now consider a series of travel reduction strategies, at the very least it expands awareness of travel options and enumerates the benefits of non-traditional work arrangements. Second, the biannual performance reviews ensure that CTR is performing well by the standards of both WSDOT and the legislature.

Compressed Workweek: Work 4 Utah

Quick Summary

In 2008, newly elected Governor Jon Huntsman released an executive order requiring that the vast majority of executive branch state employees work 10-hour days Monday to Thursday and take Friday off in order to reduce costs. Work 4 Utah was launched 2 months after the Governor's order, a launch process that included high-profile surveying and public outreach components. The 1-year pilot program, while not without shortcomings, provided the state with significant cost savings and brought national attention to compressed work weeks. The program has since been evaluated and renewed due to its success reducing overhead costs. About 17,000 employees and nearly all state agency offices in Utah have a 4/10 work week.

Impetus

Utah governor Jon Huntsman made national headlines in June 2008 with an executive order[9] that required 17,000 state employees (about 80% of the executive branch workforce) adopt a 4-day workweek (*50*). The program, called Work 4 Utah and referred to as the "4/10" arrangement, would require most state employees to work 10 hours each day from Monday through Thursday and take Fridays off. The program was launched as a 1-year pilot program to conserve energy, save money, improve air quality, and enhance customer service within government agencies (*51*). Observers credit high gas prices,

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[9] The Executive Order #2008-0006 was one of the first issued by Gov. Huntsman after he assumed office.

Utahans' preference for earlier and later access to government services, and the desire to cut government spending on energy as key motivators for the switch (*52*, *53*, *54*).

Implementation

The Governor's Office began by undertaking several outreach initiatives in the 2 months before the change to a 4/10 schedule would be made in August 2008. The initiatives were meant to quickly disperse information about the program, establish a baseline from which to evaluate the project, and address agency-side implementation problems before they surfaced. The three most important initiatives included the creation of a hotline, projection of expected cost savings, and the production of a baseline report.

First, a Work 4 Utah hotline was established and a fully staffed call center was set up to answer questions by the public, affected employees, and local government officials. Calls to the hotline greatly declined shortly after the program was in place and the state was able to downsize the hotline.

The Governor's Office projected estimates of the project's annual economic impact. The economic impact study made a conservative estimate of projected annual benefits to the state. The estimates suggested that Utah would save $14 million annually from foregone vehicle operation, state savings from utility expenses, and "additional GDP due to reallocated expenditure of savings" (*55*). The study chose not to project benefits to the environment, savings on building operational costs, and improved customer service until further study could be done.

A Baseline Report was widely circulated to explain the program's methodology, provide guidance to agency leadership, and address frequently asked questions by the public and affected employees. The focus of the report was on the responses of state agencies to a five-question survey that asked how each agency planned to handle various aspects of a four-day workweek. Answers regarding how the agency would monitor the program's effectiveness, communicate with customers, help employees transition, and maintain productivity were displayed as statistics and a list of innovative answers were given special attention.

Results

One year after the switch, Utah conducted an extensive survey and analysis that compared actual and projected cost savings, put employee opinion in perspective, and assessed the environmental impacts for the first time. Interestingly, the final report does not mention traffic or congestion savings and does not mention a relationship between Work 4 Utah and transportation.

Regarding cost savings, the 1-year report found that first-year savings were modest, but significant. Overall energy savings after 1 year were about 10.5% among *all* state buildings and about 13% among those on a 4-day workweek. The state could not achieve

20% reductions at all 4/10 worksites because it was not always possible to turn off each building's unique utility system. New control technologies were installed midway through the pilot year. Before the actual cost savings data was published, local leaders thought the switch had saved money. Over 70% of local government leaders said that the 4/10 workweek is a "good way" for the state to try and save money. This kind of consensus showed that Work 4 Utah was unlikely to be cut due to internal pressure that stems from conflicting opinion on the program's usefulness.

The switch to a 4/10 workweek impacted employees negatively in fewer ways than expected. The survey learned two important things. First, most employees liked the switch. After 1 year, 75% of employees preferred the 4/10 schedule (up from 56% who said they would like it). Only 18% reported disliking the new arrangements. Second, the survey found that workers over-estimated the potential negative side-effects of the program. Employees surveyed before the 4/10 workweek was established anticipated more problems with childcare arrangements and public transportation use than actually surfaced. After one year, only 9% of respondents indicated a negative impact on childcare (down from 20% before) and 8% saw a negative impact on public transportation (down from 14% before).

From a customer relations standpoint, local governments suffered most. Of local government leaders, 37% had a harder time doing business on Friday due to the closures, whereas only 22% of the public felt the 4/10 schedule was inadequate. Data from Utah.gov found that significantly more business was done online during the pilot. Business registration renewals, hunting and fishing licenses, criminal background checks, and income tax filings performed online increased substantially during the Work 4 Utah program. In light of the favorable findings, Work 4 Utah was extended with certain exceptions in December 2009. The extension plan kept the vast majority of state offices on the 4-day workweek but let key Utah Tax Commission and Department of Public Safety offices stay open on Fridays.

Best Practices

Among the case studies considered in the document, Work 4 Utah has produced the highest cost savings, highest return on investment, and is arguably the most sustainable alternative work arrangement. All of these positive attributes can be credited to the mandatory nature of the program. Because state agencies were required to close on Friday, the cost savings were much greater than they otherwise would have been under a voluntary or site-by-site implementation plan. Additionally, the fact that all state agencies made the switch provided consistency that helped the public and local governments adapt to the program. Imagine if Work 4 Utah gave agencies a choice regarding which flexible work arrangements to adopt. Different agencies might choose a 4/10 workweek and close on different days, thereby confusing the citizens and local governments they serve. Others might adopt flextime that would keep the offices open longer each day, potentially increasing overhead costs.

As a congestion mitigation strategy, Work 4 Utah leaves something to be desired. This author could not find any quantitative assessment of Work 4 Utah's effect on congestion and therefore little can be said about its impact on traffic. Perhaps this data is unavailable because improved transportation was not one of the program's goals and Utah's Department of Transportation was not the founding party. However, because the program immediately impacted a large number of commuters, significantly altering their travel schedules, it is easy to imagine that Utah roadways experienced at least short-term reductions in weekday congestion. This program permanently moved 17,000 commuter trips away from the peak periods each day and eliminated commute trips one day a week. Whether quantified in an official study or not, one cannot say that Work 4 Utah is not an example of a successful—and maybe accidental—congestion mitigation strategy.

TxDOT Maintenance Crews 4-day Staggered Work Week (Abilene, Texas)

Impetus

In March 2008 the Abilene and Odessa districts within TxDOT implemented a compressed work week for the Maintenance Operations crew in order to reduce operating expenditures and improve productivity associated with sign replacement, street sweeping, pavement repair, and other maintenance tasks. The program was championed by District Engineer Russell Lenz. Because the program was conceived of, designed, and launched by TxDOT management, implementation costs for the program were near-zero. The two districts saw fantastic improvements in efficiency and significant cost savings after a 3-month trial period.

Implementation

The Abilene and Odessa districts divided their Maintenance Operations crew into two teams that would each work a staggered 4-day week. Employees on the "A schedule" would work Monday to Thursday while employees on the "B schedule" would work Tuesday to Friday. The following week, the schedules were reversed so that "A schedule" worked Tuesday to Friday while "B schedule" worked Monday to Thursday. The alternating schedule created a 4-day weekend every other week, so employees could schedule personal businesses on either Mondays or Fridays.

The 4-day and 5-day schedules are compared in Table 1. Notice that the compressed 4-day schedule increases amount of the work day spent on production from 5.5 hours/day (62%) to 7.5 hours/day (71%) while shortening the number of hours worked per week and reducing the time spent staging, traveling, and setting traffic controls. A compressed work day starts 1 hour earlier and ends half an hour later, so the compressed work week uses fewer man-hours than the 5-day schedule.

Results

After 3 months of operation, TxDOT performed an internal evaluation of the compressed workweek. Their investigation concluded that the compressed work week offered substantial cost savings, increased productivity, and a generally happier workforce. Some key findings include:

- 52,758 equipment miles saved
- $19,232 cost savings from water and fuel reductions (calculated)
- Large efficiency improvements in large and small sign work, street sweeping, and in-place repair of base/subgrade
- Positive employee feedback, although some employees preferred the standard 5-day work week

The compressed work week proved a solid business decision. At virtually no cost, the Odessa TxDOT district created a program that generated large cost savings and improved productivity. As a human resources decision, the 4-day work week was a work-in-progress. Due to employee preference for a consistent schedule, the Odessa district currently operates on a consistent 4-day work schedule instead of the alternating schedule. Additionally, many employees had to make special child care arrangements to accommodate the extended work day. The Odessa district has not implemented a program to help employees arrange or afford additional child care, but has worked with those employees individually to meet their childcare needs.

Seattle Housing Authority (Seattle, Washington)

In 1998 the Washington State University Cooperative Energy Program conducted a case study of the Seattle Housing Authority (SHA) to find alternative transportation solutions for Washingtonians. The study was updated in 2005 by Commuter Challenge, a non-profit organization. SHA implemented flextime in 1992, compressed workweeks in 1993, and telework in 1997, all at zero cost (*51*). The quasi-government housing agency started offering flexible schedules to its employees for two key reasons: to allow employees to avoid heavy traffic and to be more accessible to the public and their residents. SHA's Human Resources Director, Charles Hayashi, says, "This program meets our corporate needs and makes effective use of our workforce (*51*)." The agency allows employees to choose a start time between 6:00 and 10:30 am. SHA supervisors must approve the schedules, while a timekeeping system logs and tracks employee work hours.

By 2005, over 70% of SHA staff took advantage of flextime, while 3% were using a compressed workweek. Managers and employees have both enjoyed benefits. Dick Woo, Director of Finance and Information Technology, claims, "With proper planning, different start times can make flow of work between staff and management more efficient (*51*)." Telecommuting rates remain somewhat small, (also at 3%) but the option is still available for 25% of the staff. Formal telework policy agreements between staff and management ensure employee accountability and smooth operations without infringing on the employee's ability to fully take advantage of telework.

SHA also provides a web-based portal for users to access the company's database via a personal computer. Most importantly, the programs are very popular with staff as it gives them an opportunity to avoid traveling during the most congested times, both in the morning and evening. Although measurable impacts to congestion are unknown, the absence of any implementation expenses makes this a cost-effective method of removing vehicles from the roads at congested times.

IBM (Worldwide)

One of the many large corporations embracing changes to the typical work environment is IBM. The technology and consulting firm started allowing telecommuting in the mid-90s and by 2006 had nearly 40% of its 330,000 employees working from home or elsewhere on any given day. The company uses Metaverse, a Second Life website, which creates a virtual, efficient online environment where remote workers can collaborate with each other as well as employees and managers in the office. The company estimates about $50 million in annual savings from the elimination of workspaces alone. The company also saw an increase of 10 to 20% in productivity rates of teleworkers relative to their in-house counterparts as well as a higher retention rate (*32*).

Although most IBM teleworkers are generally satisfied with telecommuting, some felt they lacked a strong connection with their coworkers and were missing out on institutional knowledge and promotions. In order to keep teleworkers more connected, IBM rekindled IBM Club, a mixture of intramural sports, picnics, and other social and recreational activities. The independently, locally run clubs allow employees to "come together, to network, to get to know each other," says Mary-Ann O'Connor, a mobility specialist at IBM. The clubs have been very successful, with over 90,000 members in 2006 (*52*).

Dell (Worldwide)

Dell is a leading computer and technology firm with hundreds of offices worldwide, including a major corporate center in Texas. After a global survey of its employees, Dell found that work schedule flexibility was desired by a majority of the workforce. Therefore, in December 2010, Dell established the Connected Workplace initiative with the basic principle of enabling its employees to work when and where they feel most productive. The initiative incorporates many forms of flexible work options, including telework, flex days, and compressed work weeks. To ensure successful implementation, a plan must be established between employee and manager to meet one key requirement: An employee with an alternative work arrangement must be able to complete all required work normally completed when in the office. A home office set-up allowance is given to teleworking employees as well as a laptop computer. A virtual private network (VPN) allows employees to safely access the Dell network with their laptops in the same way they would if they were in the office. Investments in training and education ensure all employees understand the work arrangements and know how to interact in a virtual environment (33).

In the short time of its existence, Connected Workplace has over 3,000 formal participants in Central Texas alone. Of those participants, almost 75% telework 1 to 4 days per week and about 18% are remote workers, which mean they almost exclusively work off-site and require no office space. According to Dell's Human Resources department, a significant fraction of employees telecommute and flex their schedule informally as well (33).

Dell has experienced high employee approval and better customer service as a result of contributing programs. In prior flexible work pilots, Dell's call centers have experienced better customer satisfaction by shifting their service time from 8:00 a.m.–5:00 p.m. to 10:00 a.m.–7:00 p.m. to allow costumers more time in the evening to resolve computer issues. One goal of the program from a company perspective is to maintain business continuity. In the case of a natural disaster, inclement weather, or even a sick day, teleworkers can continue to operate from their homes and continue to serve customers and coworkers (33).

Flex in the City (Houston, Texas)

As part of former Mayor Bill White's Flexible Workplace Initiative, Houston's "Flex in the City" encourages companies citywide to use flexible work options, such as telecommuting, flextime, and compressed workweeks, at the same time for up to 4 weeks. The program not only allows employees and employers to gauge whether these alternative modes will work for them, but it also allows traffic engineers to understand roughly how many people could flex their schedule or telecommute given the option (*53*). During the 2006 pilot program, 140 organizations participated, leading to 9,000 employees eliminating their peak hour commute. Engineers used TransStar, a transportation management tool that uses over 730 cameras to monitor Houston's freeways, to measure the initiative's effectiveness. On the two highways analyzed, IH 45 and US 59, a 1.7-minute (5.9%) reduction in commute time was calculated on average. The aggregated cost savings for commuters on the two highways was $16.8 million based on the 906 hours of daily commute time saved. In a followup survey, 68% of participants found their commute to be faster or much faster than previously, 96% found their productivity to be the same of higher than previously, and 50% planned to continue working in a flexible schedule as a result of Flex in the City (*54*). Investing in a similar pilot program could be a possible next step that TxDOT could take to understand the effectiveness of these travel demand tools.

CONCLUSION

Traffic congestion occurs when travel demand exceeds capacity. Solution of the congestion problem can theoretically be accomplished by reducing travel demand or increasing system capacity or both. Travel demand management is a desirable part of the solution because it is very cost effective—that is, it typically involves very small investments that might produce large effects.

It is unlikely that demand can be managed to ensure free-flowing traffic during peak hours without sweeping, mandatory measures. As cities grow around existing transport infrastructure, a greater number of travelers will try to use the system to which capacity can be added, but with very high cost. Demand management programs that encourage drivers to make trips during non-peak periods can better utilize system capacity and allow urban transportation systems to economically serve a greater number of people.

Attempts to reduce congestion to a socially acceptable level would be maddening. Travel delay is measurable and can be interpreted as a cost to society, but congestion is a matter of place and perception. How Houstonians think about congestion is likely very different from how Fredericksburg residents think about congestion—one might complain about 25-mph highway traffic while the other complains about waiting through an extra traffic signal cycle during rush hour. To these constituents, their current level of congestion is frustrating and unacceptable. Is it feasible and prudent to "fix" congestion for both travelers?

In theory, flextime, flex days, and telework can effectively reduce total travel demand and provide relief to congested roadways at a very low cost. These voluntary approaches to demand management are much more politically palatable and socially acceptable than road pricing mechanisms. Mandatory devices such as tolling have proven to be effective in reducing congestion, but the number and scope of potential toll projects is limited by economic, environmental, social, and political considerations. Providing employees with alternatives to a peak hour commute eludes the barriers associated with mandatory demand management while still reducing peak travel demand.

Flexible schedules and telecommuting not only benefit the general commuting population by decreasing peak hour trips, they also provide benefits to the participating employees and employers. Studies show employees prefer flexibility in their schedules so they can be more productive, better manage the home-work balance, and avoid the stress associated with sitting in peak hour traffic. In addition, employees save on commute costs by decreasing fuel consumption and reducing travel time. Washington State's Commute Trip Reduction (CTR) Program and Minnesota's eWorkplace have had overwhelming acceptance rates from its participants.

Employers are also beginning to make the shift away from the typical nine-to-five work day because it makes sense from a business standpoint. Companies like IBM and Dell are improving their bottom line by reducing office space and lowering electric bills, while their employees working outside the office are increasing output. Although flexible work arrangements are not plausible for many employees or businesses, they have been implemented successfully in a wide cross section of the public and private sectors.

Based on the findings of this research brief we recommend the following:

- **Further research into the area of flexible work arrangements is not necessary**. The numerous studies over the past 30 years have determined the benefits, caveats, and best practices of flexible schedules.
- **Flexible work arrangements should be a part of TxDOT's demand management toolbox because of their high cost effectiveness**. Although their effects on congestion have been modest, flexible work programs come at little to no cost to a public agency. Many large, successful demand management programs have been funded by state and national grants as well as an increasing investment from the private sector.
- **TxDOT should take a leadership role in demand management** by coordinating with various public agencies in the urban areas of Texas, where congestion is most severe. Because TxDOT is not the state agency responsible for congestion mitigation, organizing comprehensive demand management strategies among all public agencies will be vital for a successful implementation program. For example, the Austin district of TxDOT can work with the Capital Area Metropolitan Planning Organization (CAMPO), the City of Austin, and even large private firms to promote flexible work arrangements and measure the affects in the Austin area.

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Texas Department of Transportation

Providing safe, effective, and efficient movement of people and goods.

Strategic Research Program – Research Brief 002

The Problem of Congestion and Mass Transit

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Purpose

The Texas Transportation Commission established the TxDOT Strategic Research Program in 2011 to assist the Department with its Number One Goal: Preparing for the Future. This series of research briefs is intended to identify and frame transportation challenges Texas will face over the next 10-30 years. In support of that goal, the briefs attempt to spur discussion within and outside of TxDOT to address issues that TxDOT's stakeholders, interest groups, the Texas Legislature, TxDOT Administration or the Transportation Commission foresee affecting the efficiency and viability of the state's transportation system.

Using current literature, interviews and other sources, briefs are meant to provide the reader with an overview of the subject and emphasize the strategic elements of a topic that may need further development, either focused research or internal TxDOT actions. The briefs themselves are not intended as a detailed examination of current or planned TxDOT activity.

This research brief takes a macroscopic look at different congestion mitigation strategies used worldwide, specifically examines strategies using mass transit, and identifies areas for further, more detailed, analysis by TxDOT.

Congestion is a major problem throughout the United States.

Introduction

Congestion is a major problem throughout the United States. It not only afflicts highway systems but also halts traffic in urban areas. Congestion is also a serious problem throughout Texas, especially in the large metropolitan areas. To address this issue, multiple congestion mitigation practices are already used in Texas, including:

- Tolling
- High Occupancy Vehicle (HOV) lanes
- Mass-transit standards
- Light rail systems

However, many of the current methods of congestion mitigation have become inadequate, and the Texas Department of Transportation (TxDOT) seeks to find new methods to alleviate congestion. Of particular interest are solutions using public transportation. This research brief demonstrates the need for improved congestion mitigation practices, differentiates between different public transportation solutions, and highlights recommended solutions and actions that TxDOT should pursue. Adopting these techniques will be invaluable to contain the inevitable increase in congestion that will accompany an increased population 20 years in the future, as the population of Texas is expected to reach between 32 and 41 million by 2030 (Gaines, 2008).

Situation Review

Nations around the globe have adopted many different practices in an attempt to alleviate congestion. The United States is no exception, with a variety of different solutions being used in different regions to address congestion in crowded urban areas. The State of Texas has adopted several different practices and continues to develop and acquire new solutions. While many of these practices have been shown to be effective, data also show congestion is still increasing in many urban areas. Figure 1 shows a congested freeway in Houston, Texas. Many of these congestion mitigation solutions focus less on the use of mass transit than on effective policy. By continuing to implement new technologies and solutions, particularly public transportation, the United States may be able to reach a level of congestion comparable to that of other countries.

There are a wide range of solutions practiced globally to effectively eliminate congestion.

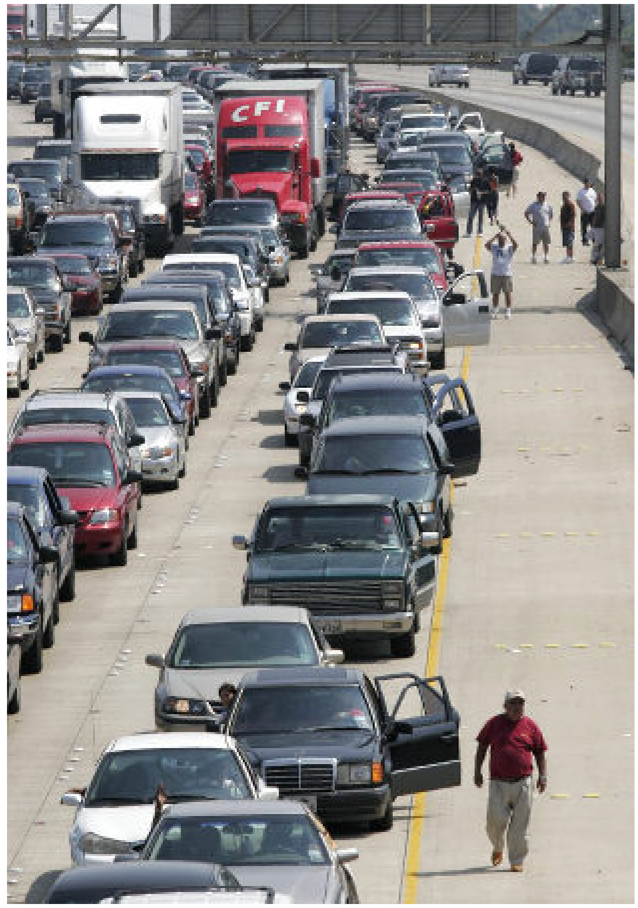

Figure 1: Congestion in Houston, TX
(Source: Getty, 2009)

There are a wide range of solutions practiced globally to effectively eliminate congestion. Many nations use various forms of mass transit to varying levels of efficacy. Among these nations are France, Japan, Indonesia, and Singapore. In France and other areas of Europe, commuters are able to use high speed rail lines at speeds competitive with commercial airlines and in greater comfort than personal vehicles (Davey, 2001). In Japan, passengers can ride magnetic levitation trains at high speeds to avoid congested highways (BNET, 2004). In Indonesia, passengers are able to essentially "carpool" in public vans, thereby limiting the number of private vehicles used (Arintono, 2010). In Singapore, massive underground railway systems are used to transport large numbers of passengers, greatly reducing traffic as shown in Figure 2 (Railway-Technology.com, 2010). It is likely these solutions could be implemented and used effectively to decrease congestion in the United States.

Figure 2: Commuters at the Dhoby Ghaut Railway Station in Singapore
(Source: Railway-Technology.com, 2010)

On a national level, many different practices are used to alleviate congestion in the United States. A large number of these solutions are policy-related, so it is likely that the United States could benefit by implementing mass transit solutions. Among these solutions are tolling, growth management, and improved standards. According to the New York State Department of Transportation (NYSDOT) Traffic Congestion Mitigation Commission (TCMC) in 2008, tolling can be a very effective policy to reduce congestion on crowded highways. However, this may simply shift traffic to another location, so it may not always be a feasible long-term solution. Growth management is a practice of focusing urban development in areas with developed public transportation systems in order to promote more use of mass transit. Many cities have growth management policies, and it is likely such policies can effectively reduce traffic in developing communities in Texas (Deal et al., 2009). A final policy is to improve current transit standards to foster more efficient transportation. Many transportation associations advocate improved standards and claim that such policies can improve traffic situations in urban areas (APTA, 2010).

The State of Texas uses a combination of both public transportation and other policies to alleviate congestion on highways and in urban areas. In addition to the various mass transit solutions, many Texas cities also use other methods to mitigate congestion. According to the Texas Transportation Institute (TTI) in 2009, these methods often include:

- Arterial street signal coordination
- Freeway ramp metering
- Arterial street access management
- HOV lanes
- Freeway incident management

Although these methods can prove effective in some situations, data suggest that congestion is still increasing, so it is likely that the state could benefit by using alternative methods of congestion mitigation.

Many cities in the state already use different mass transit methods to reduce congestion and meet consumer demand. One such method adopted by Dallas and planned for and advocated in other cities is a light rail system. After opening in 1996, Dallas has effectively used a light rail system called the Dallas Area Rapid Transit (DART) to provide an alternative means of transit and reduce personal vehicle use. In 2000, a light rail system was rejected in San Antonio, but many still advocate for such a system, and it is likely that other cities in Texas and around the country will develop more light rails to improve transit (Light Rail Progress, 2000). Another recent development in the state is a new focus on passenger rail transportation between cities. In order to compete with other states and improve transportation conditions, TxDOT has developed a rail division and plans to take advantage of increased federal funding for building a passenger rail system (Texas Rail Advocates, 2009). Continuing to improve public transportation will likely produce numerous beneficial results for the State of Texas and help to alleviate some congestion in the large metro areas.

Problem Development

Traffic congestion consists of the incremental delay resulting from interference between vehicles in the traffic stream.

Data in the United States indicate that congestion is a serious problem in many cities. According to the Victoria Transport Policy Institute (VTPI) in 2010, traffic congestion consists of the incremental delay resulting from interference between vehicles in the traffic stream. This problem results from the volume of vehicles on a roadway exceeding the capacity of that roadway. According to the VTPI (2010), such congested conditions can create numerous problems for commuters, including:

- Driver stress
- Vehicle costs
- Crash risk
- Pollution
- Increased travel time

Unfortunately, data suggest that congestion is worsening, so unless unique solutions are sought and implemented, it is unlikely that these complications will cease. In 2006, the Federal Highway Administration claimed that half of the population of the United States lives in large metro areas. Within these areas, four out of five workers think congestion is a problem. Figure 3 shows how the average speed of commuting has decreased over the last two decades as the duration of the commute increased.

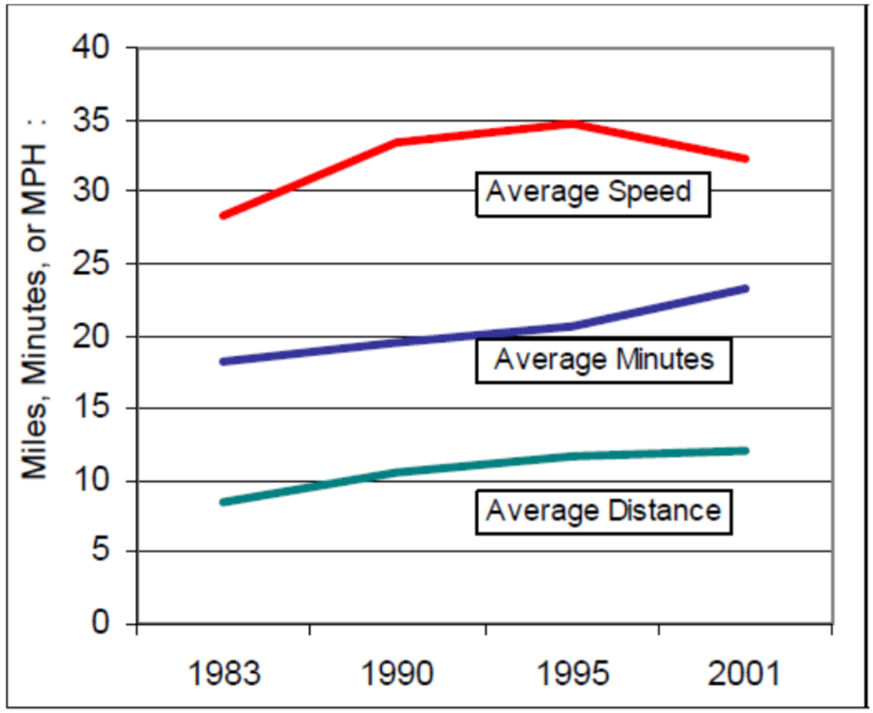

Figure 3: Miles Minutes, and Speed Changes in Daily Commutes from 1983 to 2001 (Source: FHWA, 2006)

However, congestion is not simply an issue for work commuters. The number of non-work related trips is steadily increasing, as shown in Figure 4 (FHWA, 2007). In fact, the average American is making four more trips a week for non-work purposes than were made a decade ago (FHWA, 2007). This increase in trips has greatly compounded the amount of congestion in urban areas.

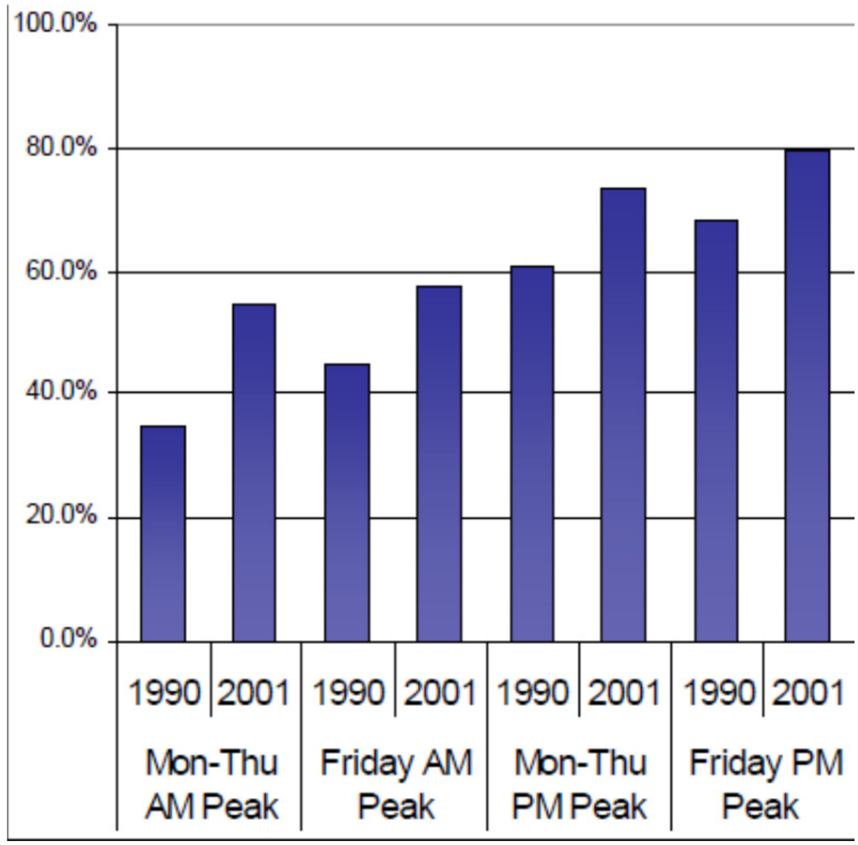

Figure 4: Non-Work Trips at Peak Periods
(Source: FHWA, 2007)

With the number of trips made weekly increasing for both work and non-work purposes, it is very likely that congestion will continue to increase, thereby increasing travel time for commuters. Travel time in Texas has already increased greatly from 1982 to 2007 (TTI, 2009). During this period, the Travel Time Index, a ratio of travel time in the peak period to the travel time at free-flow conditions, increased significantly for several Texas cities. These increases are shown below.

- Houston: 1.19 to 1.33
- Dallas: 1.05 to 1.32
- Austin: 1.07 to 1.29

Other problems have accompanied these Travel Time Indexes. Texas cities have experienced increases in average annual delay per traveler and wasted fuel. The average commuter in Houston is likely to experience 56 hours of annual average delay and waste 40 gallons of fuel per year (TTI, 2009). These problems are unlikely to resolve unless creative solutions are sought.

Generic Solution

Mass transit has advantages over other means of transportation because it allows many users to be transported through large metropolitan areas.

Many areas in the United States, including Texas, have experienced an increase in congestion and traffic levels on highways and in urban areas. Such high traffic results in numerous complications for travelers. Although many different techniques for combating congestion exist and are used in the United States, the growing level of congestion has rendered these techniques insufficient. A possible solution to this dilemma is to adopt global solutions and improve mass transit. Mass transit has advantages over other means of transportation because it allows many users to be transported throughout large metropolitan areas, thereby limiting the number of personal and other vehicles used (Schofer, 2011). This mode of transportation can greatly reduce the problems caused by high congestion that were previously mentioned. Additionally, it is believed that improving mass transit conditions can save cities millions of dollars in terms of the monetary value of vehicle-kilometers traveled. Aftabuzzaman et al. suggested in 2010 that Houston could save an estimated $110 million ($108 in Australian dollars) by switching from a predominantly personal-vehicle system to a mass transit system. By improving various aspects of the mass transit system in Texas, TxDOT can greatly improve traveling conditions throughout the state.

Specific Solutions

Although there are numerous factors involved in the efficacy of mass transit, the research team has focused on four specific solutions that can be used to improve congestion conditions in Texas. These four areas are:

- Engineering
- Deployment strategies
- Policy
- New Technology

This section will examine the relative advantages, disadvantages, and applications of each of these four fields and discuss how these solutions could be used to improve congestion conditions.

Engineering

One simple area that can be improved easily and impact the efficacy of mass transit systems is in engineering. Roadways can be engineered to better accommodate mass transit systems. An example of this is transit "Pass-Through" lanes, which are often used at freeway interchanges. This engineering system works by providing preferential treatment to buses and other forms of public transportation using freeways, allowing them to bypass other vehicles at interchanges in order to provide a more rapid and economical trip (Mandelzys and Hellinga, 2009). This type of solution is easily adaptable and can be used throughout Texas. Another example of sound engineering practice for mass transit is the use of high-speed locomotives on current rail systems. Many current and future high-speed rail locomotives are multifunctional and are compatible with older, pre-existing railway lines, allowing commuters greater access through public transportation (The Economist, 2010). This solution, too, is easily adoptable. Improved engineering practices could greatly reduce congestion in Texas.

Benefits

Sound engineering practices in mass transit can produce many benefits. These benefits include:

- Decreased trip-time for users of mass transit (Mandelzys and Hellinga, 2009)
- Ease of integration with current systems (The Economist, 2010)
- Reduction of personal vehicle use, thereby eliminating congestion (Railway-Technology.com)
- Economic benefits for cities with rail (Sperry and Morgan, 2010)

Disadvantages

Despite these advantages, there may be some disadvantages to focusing solely on the engineering aspect of mass transit. These disadvantages include:

- Developing new infrastructure could be costly (Keating)

- Commuters may protest to preferential treatment of public transportation
- Funding for new projects may be scarce
- Using existing infrastructure may harm industry (The Economist, 2010)

Applications

Improved engineering practices can be applied in numerous situations throughout Texas. Many of these situations have already been discussed and include:

- Freeway interchanges
- New highways
- Existing rail lines

It seems obvious that improving engineering practices should be considered when determining the best way to alleviate congestion.

Deployment Strategies

One effective way to eliminate congestion and improve mass transit is to utilize better deployment strategies. Data show that mass transit is only effective under good management. More vehicles offering service to commuters does not necessarily equal better service. An example of this is the intercity van service in Indonesia. In 2010, Arintono suggested that organizations operating intercity van fleets in Lampung could actually benefit from a smaller, better managed fleet size. This practice would decrease the number of vehicles on the streets and improve travel time, thereby eliminating two of the issues involved in congestion. Better deployment policies could be applied in Texas in order to improve mass transit (Arintono, 2010). The advantages, disadvantages, and applications of deployment strategies are discussed below.

Advantages

There are numerous advantages to improving deployment strategies for mass transit systems. These strategies include (Arintono, 2010):

- Reduced fleet size
- Shorter travel time
- Improved quality of available transit

Disadvantages

Despite the advantages of improving deployment strategies, there are also some disadvantages to focusing solely on this aspect of mass transit. These disadvantages include:

- Possible decrease in income for mass transit operators (Arintono, 2010)
- Possible decrease in future capacity for transit operators
- Enforcement of policies on local agencies

Applications

Better deployment strategies could easily be applied in any cities that use mass transit systems such as buses or light rails. TxDOT should consider ways to improve management conditions and advocate improved deployment and scheduling in urban areas where mass transit systems exist.

Policy

Several emerging policies have been shown to improve mass transit systems in various areas. One such policy is growth management. By focusing development in areas with existing transit and promoting growth and use of transit in developing areas, growth management has been indicated to greatly increase mass transit use (Deal et al., 2009). Promotion of mass transit decreases personal vehicle use, thereby limiting congestion. Another effective policy uses emerging technology to allow users to determine optimal mass transit use conditions for various travel time and distance scenarios. Adopting this new technology improves relations with transit users and provides an adequate assessment of the efficacy of a mass transit system. Therefore, this policy of adopting new technology and interacting with transit users could lead to greater transit use and decrease congestion (Cheng and Agrawal, 2010). The advantages, disadvantages, and applications of improved policies are shown below.

Advantages

Improving mass transit policy could greatly improve mass transit conditions. The advantages of improved policy include:

- Increased transit use in developing communities (Deal et al., 2009)

- Increased interaction with transit users (Cheng and Agrawal, 2010)
- Improved efficiency of mass transit system (Cheng and Agrawal, 2010)

Disadvantages

Despite these advantages, there are several disadvantages to focusing solely on policy improvements. These disadvantages include:

- Little impact on new development outside of growth management areas (Deal et al., 2009)
- Increased effort to educate public (Cheng and Agrawal, 2010)
- Could be costly to implement new technologies

Applications

Policy improvements are applicable in numerous situations. These situations include:

- Developing communities
- Existing communities with poor mass transit ridership
- Areas with limited mass transit capacity to meet demand

These applications indicate that most urban areas could benefit from improved mass transit policies. Therefore, TxDOT should consider improving policies as one way to improve mass transit conditions and decrease congestion.

Technology

New technologies are constantly developed to improve mass transit. Many of these technologies provide more cost-effective means to transport greater numbers of passengers. Some designs even allow for integration with existing highway systems. One such emerging technology is a straddling bus system currently under development in Hong Kong. A straddling bus is essentially a wide bus that travels on a fixed track above an existing roadway, as shown in Figure 5. It allows multiple passengers to travel rapidly without adding extra vehicles to the roadway, thereby decreasing congestion (Wassener, 2010). Another new form of technology to solve mass transit problems is a Web-Public Transit Information System (W-PTIS). This system integrates GPS or other location-tracking technology, the internet, and personal hand-held devices (such as smart phones) to provide real-time information to transit users about the location of transit vehicles. This technology allows users to more accurately determine where a vehicle will be and plan for waiting times. It also allows transit operators to increase efficiency in scheduling and fleet size, thereby improving the entire transit operation and helping to eliminate congestion (TransTech Lab, 2011). The advantages, disadvantages, and applications of applying new technology to improve mass transit conditions are discussed below.

Figure 5: Straddling Bus Concept
(Source, Wassener, 2010)

Advantages

There are numerous advantages to using emerging technology to improve mass transit. These advantages include:

- Integration with current infrastructure
- Possibility of greater energy efficiency
- Possibility of increased safety
- Real-time information for transit users
- Decreased waiting time

Disadvantages

Despite these advantages, there may be several disadvantages to focusing solely on emerging technologies to improve mass transit conditions. These disadvantages include:

- Possible high cost for initial implementation
- Unforeseen safety issues

- Unforeseen environmental impacts
- Possible regulations on GPS technology

Because this solution requires considering new and possibly undeveloped technologies, it is difficult to determine what the advantages and disadvantages of new mass transit systems may be. Further research is advised before any new technology is adopted.

Applications

There are myriad applications for new technologies, so further research is needed to determine where and how these technologies could be used to improve mass transit systems.

Various aspects and conditions of these systems should be researched in order to allow the State to make use of the most effective engineering practices, deployment methods, policies, and new technologies.

Conclusion

Mass transit systems can be used to solve the transportation dilemma in Texas. However, various aspects and conditions of these systems should be researched to allow the state to make use of the most effective engineering practices, deployment methods, policies, and new technologies. Possible research paths to follow in order to determine how best to improve mass transit and eliminate congestion are discussed below.

Engineering

There are multiple research projects that could be conducted to determine the efficacy of improving engineering practices for mass transit systems in Texas. These include investigating the ease of implementation of "Pass-Through" lanes, determining the environmental impacts of altering existing infrastructure, and locating funding sources for changing infrastructure. Improving engineering practices may be the easiest changes to mass transit for TxDOT to make in many circumstances, as it may require no more effort than retiming signals and providing passes to buses. This is an effective change that could significantly reduce congestion in busy metropolitan areas with bus systems over the next few decades.

Deployment Methods

There are two possible research paths for improving deployment methodology. One project could be to investigate how TxDOT will deal with and enforce policy with local and municipal government agencies for regulations on deployment methods. A second project could study the economic impact of increasing or decreasing mass transit fleet sizes in urban cities such as Dallas and Houston.

Policy

There are multiple research topics involved in improving mass transit policies. One topic could be to investigate the economic impact of growth management systems on a developing community. A second topic could be to investigate how TxDOT and the state government could regulate growth management policies in developing areas, such as the Dallas-Fort Worth Metroplex. A final topic could be to investigate the ease of convincing the public to use transit mapping software.

Technology

Researching new technologies are likely the most extensive research projects that TxDOT could undertake. Among the possible topics that could be investigated are:

- Ease of implementation for new technologies like straddling buses
- Ease of implementation for installing and integrating GPS into public transit
- Environmental impacts of new technologies
- Cost of changing infrastructure to accommodate new technologies
- Public acceptance of new systems such as straddling buses
- Safety of implementing new technologies

After careful research and planning, it is likely that TxDOT could use mass transit to improve commuting conditions for Texans.

The topics could each be researched extensively, and some could even produce new research topics themselves. This category of strategic research is a very complicated topic and would need to be approached from multiple angles.

Transportation in the State of Texas is in poor condition. Congestion on highways and in urban areas continues to increase, and the current means of transportation and congestion mitigation are inadequate to meet growing demand. An improvement to the existing mass transit system in Texas is one solution that could greatly reduce congestion and improve transportation conditions. By adopting global practices in engineering, deployment methodology, policy, and technology, it may be possible for TxDOT to augment the current mass transit system. However, careful research into various topics, such as ease of implementation, cost, safety, environmental concerns, and relations with local governments should be made before any solution is applied. After careful research and planning, it is likely that TxDOT could use mass transit to improve commuting conditions for Texans. These policies could not only affect congestion levels in the immediate future but also in decades to come. New technologies, in particular, seem essential for improving congestion conditions. TxDOT should explore emerging technologies strategically and take advantage of them in order to implement them and mitigate congestion as quickly as possible.

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About TechMRT

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The SRP program is jointly guided by a three-institution consortium comprised of the Center for Transportation Research at the University of Texas, the Texas Transportation Institute at Texas A&M University, and the Texas Tech Center for Multidisciplinary Research in Transportation.

Center for Transportation Research
The University of Texas at Austin

Research Brief #3 Determining a Comprehensive Freight Strategy for Texas

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Overview

"Strong productivity gains in the U.S. economy hinge, in part, on transportation networks working efficiently. Continued development and efficient management of the nation's freight transportation system--especially highways and rail lines that connect international gateways and intermodal facilities to retailers, producers, and consumers--are important to sustaining the nation's competitive position in the global economy. However, the increasing congestion within the freight transportation system poses a threat to the efficient flow of the nation's goods and has strained the system in some locations. Moreover, recent growth in international trade has placed even greater pressures on ports, border crossings, and distribution hubs--key links in the freight transportation system. Congestion delays that significantly constrain freight mobility in these areas could result in serious economic implications for the nation" (United States Government Accountability Office, 2008).

TxDOT's responsibility for the provision of state highway infrastructure has resulted in a comprehensive understanding of the design, maintenance and rehabilitation of highways. Quite different from rail planning in which freight is the central concern, those responsible for highway planning, have, for a variety of reasons, focused attention on auto flows, particularly in urban areas. When a transportation specialist was asked why more attention was not given to freight, the answer was "freight does not vote."[1] Economists, however, have long agreed that freight and passenger transportation infrastructure is a necessary, but not sufficient, condition for economic development. This brief argues that it is now time to capture freight movements into comprehensive transportation planning, particularly the role played by highways which provide around 60 percent of the ton-miles moved within Texas.

Freight moves on single or multi-modal systems and is dynamic, responding to commodity and shipper characteristics and competitive forces within the supply chains moving freight from producer, often through intermediaries, to final consumer. With the country's most extensive highway network along with substantial rail and marine assets, Texas has an enviable choice of transportation modes and this has helped make it the leading exporting state in the U.S. The challenge over the coming decade is how to maintain this advantage when highway funding is predicted to fall substantially given modal efficiencies and the increasing use of hybrid and alternative fueled vehicles[2].

The components of a comprehensive state freight plan vary with the adopted time horizons, which at this time are unknown. The brief therefore suggests a variety of subjects worthy of consideration by the Committee, ranging from topics of immediate relevance through to longer range subjects which nevertheless deserve recognition at this time. Specific topics for consideration include:

[1] This remained an answer given by many political advisors, including some in Texas, in the 1990s.

[2] This subject – the funding gap and alternative funding scenarios, is taken up by the recently completed 2030 Committee series of studies. See: http://texas2030committee.tamu.edu/

1. Create a vision for the Texas Freight Transportation Infrastructure of 2050 considering key drivers and given a multi-stakeholder dialogue;
2. Examine the role of transportation in the logistics chains of a sample of Texas's major industries and identify options to reduce the generalized cost of transportation and increase the efficiency of Texas's transportation system;
3. Develop a detailed freight plan for Texas that addresses, among other roles, the role of freight in serving large urban areas in the mega-regions of the state;
4. Explore the mission, purpose, objectives, and mandate of a Texas Freight Stakeholder Working group during a meeting of interested freight stakeholders;
5. Conduct a study of truck productivity and toll rates for trucks; and
6. Conduct a study to establish the bridge costs required to allow productive trucks to use key interstate corridors in Texas.

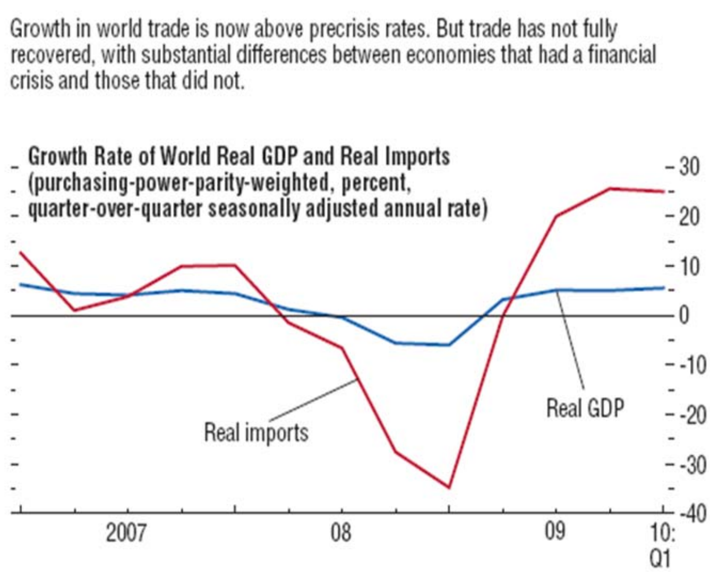
In many cases, these topics build on work in the public domain or conducted by the University participants in the RTI Department of TxDOT.

Freight Demand

The demand for freight and modal choice represents a critical element of any freight strategic plan and for highway authorities it constitutes a major, but somewhat neglected, customer for highway services. TxDOT's strategic planning therefore needs to recognize changing patterns of freight demand for all modes since it informs the institution of both demand for a specific mode like highways but also of complementary modes, like rail, that would impact shipper decisions and statewide transportation networks. The Texas economy is now global in nature and international issues have a direct relevance on the state modal systems. Freight demand at the global, national, and state levels is now presented.

Global Freight Demand

In an October 2010 report on the state of the global economy, the International Monetary Fund concluded that the current global economic recovery, while rapid, was still not on pace to fully counter the effects of the downturn.[3]



Source: World Economic Outlook, October 2010

Figure 1: Comparison of World GDP and Trade

[3] http://www.imf.org/external/pubs/ft/weo/2010/02/pdf/c4.pdf

Experience from recent crises has shown that international trade tends to decline at a more rapid rate than global GDP yet also is quicker to recover. The most recent global crisis has been no exception. Nevertheless, the IMF predicts a "protracted" gap in global import demand when compared with pre-crisis trends, indicating that sustained efforts will be needed to encourage and facilitate trade development and thereby supplement the natural rate of recovery.[4] Countries that experienced a banking crisis along with the start of the recession, such as the United States, have subsequently experienced a slower recovery.[5]

US Trends

The IMF estimates that the global economy must create 400 million jobs in the next decade to accommodate a growing workforce. The challenges of the US economy are thus also global challenges. In this context, the difficult nature of the US economic recovery becomes somewhat more understandable, though no less troubling. Reflecting on the role of the US role in global trade, international analysts warn of the danger of the world falling into the same 'bad habits' in which certain countries like Germany rely excessively on exports to drive growth, while others including the United States do not give sufficient attention to the balance of trade and rely too much on domestic consumption. For the US, this means that the goal of expanding exports and improving the balance of trade remains a strategic national priority which also has implications for global economic stability.

The last two years have been a trying time for US port gateways. Drastic changes were felt not only at container terminals but also at bulk ports due to the slowdown in industrial production and wild volatility of commodity prices. Container volumes have largely come back to the level they were prior to the recession, however ports are still weak due to the fact that almost all of them lost money in 2009 and are only now returning to profitability. Future investments will thus be tempered by a lack of cash on hand and perhaps and more cautious projections going forward.

The Texas Economy

Traditionally, the Texas economy has been dominated by the oil, gas, and petrochemical industries. Today, however, Texas has a diverse economy with a Gross State Product (GSP) of $934 billion in chained 2000 dollars (see Table 1). Overall, the state's economy grew 222% from 1990 to 2010, as measured by the growth in GSP. Furthermore, robust growth is expected in the future, with total GSP reaching $2 trillion by 2035.

[4] Ibid
[5] Ibid

Table 1: Texas Nominal Gross State Product by Industry, 1991 to 2035 (Billions of 2010 Dollars)

Industry Sector/Year	1991	2000	2010	2020	2035
Total Gross State Product (Current Dollars)	**$392.92**	**$711.95**	**$1,266.42**	**$2,045.79**	**$4,277.49**
Goods (Current Dollars)	**$109.09**	**$173.97**	**$361.27**	**$556.12**	**$884.87**
Agriculture	5.81	6.65	9.42	9.73	11.13
Mining (Oil and Gas)	26.47	39.39	137.2	184.28	193.35
Construction	15.88	35.86	58.59	112.96	258.96
Manufacturing	60.94	92.08	156.06	249.15	421.43
Services (Current Dollars)	**$283.82**	**$537.97**	**$905.15**	**$1,489.67**	**$3,392.63**

Note: Because of the method used by the U. S. Bureau of Economic Analysis in calculating real chained dollars, chained-dollar data for historical years do not necessarily sum to category totals.

Source: Texas Comptroller of Public Accounts, 2009–2010 Forecast and IHS Global Insight, Inc. (http://www.texasahead.org/economy/forecasts/fcst0910/ngspfiscal.html)

The emphasis of this brief is on the goods-dependent sectors as these are the sectors primarily responsible for the movement of intermediate inputs and final products to production and consumption industries and centers in the state, the U.S., and internationally. On average, the goods-dependent sectors accounted for 29% of the Texas GSP in 2010; by 2035 the goods-dependent sectors are expected to account for 21% of the Texas GSP.

Table 2 illustrates that the agriculture, mining, construction, and manufacturing industries are major goods-dependent economic generators in Texas. Furthermore, these industries are expected to experience growth between 2010 and 2035: 18, 41, 342, and 170%, respectively.

Texas: the Top Exporter

Total US trade in 2010 increased from $3.2 trillion after falling from a record $3.4 trillion in 2008 to $2.6 trillion in 2009. Houston, the largest trading market in the state, saw its merchandise trade with the rest of the world, including but not limited to port activity, rise to $211.5 billion with the rest of the world, up from $167.5 billion in 2009. Houston had traded $240.8 billion with the rest of the world in 2008.[6]

According to the latest Census and trade data, in 2010 the State of Texas was the leading export state responsible for 16.17%[7] of total US merchandise exports while reflecting just 8% of the US population. For comparison, California is the second largest exporter, with a share its 11.21% of exports roughly equivalent to its share of total population (12%). This critical distinction underscores the centrality of trade, and particularly of export trade, to the Texas economy.

6 "Wheels of trade spin faster for Houston Exports and imports are rising as the area leaves doldrums behind" Houston Chronicle, 20 February 2011

7 http://www.census.gov/foreign-trade/statistics/state/origin_movement/index.html#2010

After significant declines in trade volumes for almost all commodity types and trade partners in 2009, Texas's recovery in 2010 did not completely erase the after effects of the economic crisis. Given that 2009 trade statistics are likely to be an outlier, the publication of complete annual trade data for 2010 means that a reliable set of trade statistics for Texas is now available for the first time since the beginning of the recession.[8] In general terms, Texas' import activity is tied to Texas consumer demand, while the health of its export market is more closely tied demand from abroad for the heavy industrial commodities in which Texas specializes, as well as oil and other commodity prices and the value of the U.S dollar. The resumption of import demand in 2010 from the doldrums of 2009 indicates that a resemblance of 'normal' consumption activities has resumed, though perhaps not to a level necessary to strongly drive economic growth. The following table shows annual import totals to Texas in millions of dollars for the last three years.

Table 2: Texas Merchandise Imports (NAICS) (in millions)

Year	Manufactured Products	Non-Manufactured Products	Annual totals
2008	$163,724.4	$123,551.9	$287,276.7
2009	$129,829.0	$75,882.1	$205,711.1
2010	$163,474.1	$101,980.6	$265,454.8

Table 3: Texas Merchandise Export Profile (NAICS)

Year	Annual Manufactured Commodities	Percent of US total	Non Manufactured	Percent of US total	Re-exports	Annual totals
2007	138,389.2	15.2	9,724.4	7.2	20,050.8	168,164.4
2008	156,552.5	15.7	12,369.5	7.3	23,221.7	192,143.6
2009	129,020.1	16.1	9,259.2	8.0	24,767.0	163,046.2
2010	159,838.3	16.8	13,617.1	9.6	33,188.0	206,643.4

The story for exports appears to be more encouraging as the Texas total for exports for the latest year (2010) is actually higher when compared to baseline years 2007 and 2008, before the recession had entered full force. Over the last few years, manufactured goods have constituted the strongest share of exports, however since 2008 Texas has seen growth in all three major categories: manufactured, non-manufactured and re-exports. Of the three categories, re-exports add comparatively less to the economy in terms of employment than the other two categories. This partly explains why a state like California, as the national leader in re-

[8] As of January 2010, the US Census has resumed publishing state specific import statistics after having discontinued this practice in 1988. The new data allows a more complete examination of the role played by imports in each state. The census department has cautioned against making direct balance of trade calculations at the state level, due to distinctions in the way import and export statistics are collected.

exports, could see a rapid rebound in export trade in 2010 without an accompanying resurgence in employment.[9]

Texas Truck, Rail, Water, and Air Freight Infrastructure: What moves Freight?

Texas's economy depends on its transportation infrastructure to facilitate trade and the economic prosperity of the state. Table 4 describes the current freight mix by transport mode, both in tons and value, and projects volume and value to 2040. Table 4 shows that in 2007 Texas shipped an estimated $2,318 billion of freight within, to, and from the state ($281 billion in freight via multiple modes, $1,379 billion via truck, and $166 billion via rail). This figure translated into freight movements of 131 million tons by multiple modes, 1,257 million tons by truck, and 336 million tons by rail. Together truck and rail accounted for more than 64% of the total freight tonnage moved in 2007 within, to, and from Texas (FHWA, 2010).

Furthermore, by 2040 Texas will ship an estimated $5,515 billion in freight within, to, and from the state ($1,224 billion in freight via multiple modes, $3,143 billion via truck, and $296 billion via rail). This figure translates into freight movements of 223 million tons by multiple modes, 2,064 million tons by truck, and 546 million tons by rail. Truck, rail, and multimodal freight together will account for 73% of the total freight tonnage moved in 2040 within, to, and from Texas compared to 69% in 2007 (FHWA, 2010).

Table 4: Texas Freight Summary by Mode

Mode	2007	% of Total	2040	% of Total	% Change
Tons (millions)					
Truck	1,257.1	51%	2,063.9	53%	64%
Rail	335.7	14%	546.2	14%	63%
Water	91.7	4%	144.8	4%	58%
Air (includes Truck & Air)	0.7	0.03%	2.4	0%	236%
Multiple modes & mail	131.1	5%	222.9	6%	70%
Pipeline	485.2	20%	624.7	16%	29%
Other and unknown	48.7	2%	77.6	2%	59%
No domestic mode	134.9	5%	185.9	5%	38%
Total	2,485.3	100%	3,868.4	100%	56%
Dollars (billions)					
Truck	$1,379.0	60%	$3,143.0	57%	128%
Rail	$165.5	7%	$296.3	5%	79%
Water	$42.0	2%	$63.4	1%	51%

[9] "California exports soared in 2010," Feb 11, 2011.
http://www.bizjournals.com/sacramento/news/2011/02/11/californias-exports-soared-in-2010.html

Air (include truck-air)	$87.9	3.79%	$338.9	6%	285%
Multiple modes & mail	$280.9	12%	$1,122.4	20%	300%
Pipeline	$236.8	10%	$311.0	6%	31%
Other and unknown	$64.5	3%	$156.2	3%	142%
No domestic mode	$61.0	3%	$84.0	2%	38%
Total	$2,317.6	100%	$5,515.2	100%	138%

Note: Data shows combined total flows of commodities originating from Texas and destined for Texas, including both domestic and foreign shipments. Dollars are 2007 values, based on the earliest report FAF^3 year.

Source: FHWA Freight Analysis Framework (FAF^3) 2007–2040

Texas's Highway System

In 2007, TxDOT maintained 79,696 centerline miles of road that comprise:

3,233 centerline miles of interstate highways,
12,101 centerline miles of U.S. highways,
16,273 centerline miles of state highways,
40,988 centerline miles of farm-to-market and ranch-to-market roads,
6,761 centerline miles of frontage roads, and
339 centerline miles of park roads (TxDOT, 2007).

Texas's highway system facilitates the movement of truck shipments within, from, to, and through the state. Figure 2 graphs the truck shipments in terms of millions of tons that were shipped within, from, and to the state in 2007 and the anticipated truck tonnage moved by 2040. Figure 2 evidences that truck tonnage within Texas is estimated to increase by almost 60% between 2007 and 2040, and more than double for out-of-state movements. Truck movements into Texas are also expected to increase by 75% within the same time period (FHWA, 2010).

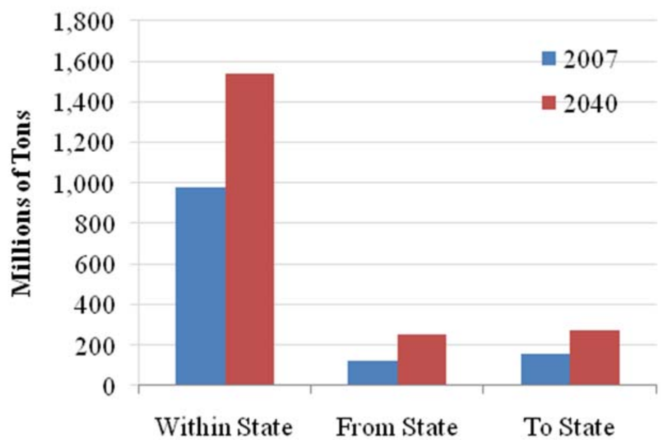


Figure 2: Truck Tonnage Moved in Texas (Millions of Tons)

In terms of goods movement by tonnage within, to, and from Texas in 2007,non-metallic mineral products (12%) topped the list of commodities moved by trucks in 2007, followed by gravel (9%), waste/scrap materials (7%), gasoline (6%), cereal grains (6%), and coal, natural sands, and fuel oils also at 5%. The biggest increase in goods movement from 2007 to 2040 is anticipated in the transportation of mixed freight (164%). According to the Standard Classification of Transported Goods (SCTG), mixed freight is composed of items (including food) for grocery and convenience stores; supplies and food for restaurants and fast food chains; hardware or plumbing supplies; office supplies; and miscellaneous goods. Thus mixed freight joins the list of top five commodities projected to be transported in Texas by 2040. The other major commodities include non-metallic mineral products (11%), gravel (7%), waste/scrap material (6%), cereal grains (6%), and gasoline, natural sands, and mixed freight at 5%.

In terms of the value of commodities moved by trucks in Texas in 2007, machinery (13%), electronics (12%), motorized vehicles including parts (8%), mixed freight (6%), and articles of base metals (5%) made up the top five commodities by value transported in Texas in 2007. By 2040, the fastest growing commodities (by value) to be transported by trucks include chemical products (275%), miscellaneous manufactured products (260%), mixed freight (157%), machinery (149%), and textiles and leather products (118%). The top five commodities (by value) projected to be transported by trucks by 2040 include machinery (14%), electronics (11%), mixed freight (7%), motorized vehicles including parts (6%), and miscellaneous manufactured products and chemical products (5%).

Texas's Rail System

Rail is a critical component of Texas's transportation infrastructure. Texas has 10,743 miles of railway, most of which is operated by Union Pacific (UP), Burlington Northern Santa Fe (BNSF), and Kansas City Southern (KCS) Railway[10]. Rail serves major border ports of entry, including Laredo, El Paso, and Brownsville, and key nodes in San Antonio, Houston, Dallas, Fort Worth, and Amarillo (AAR, 2008).

Figure 3 illustrates the rail shipments in terms of millions of tons that were shipped within, from, and to the state in 2007 and the anticipated rail tonnage moved by 2040. Between 2007 and 2040, rail tonnage moved within the state will increase by an estimated 75%, rail tonnage moved from the state will increase by 80%, and rail tonnage moved to the state will increase by 48% (FHWA, 2010). Increased rail freight movements raise concerns about the need for modernizing and enhancing rail system capacity, inadequate capacity to accommodate passenger trains on freight rail track, landside access concerns to rail intermodal yards, safety and security at at-grade road-rail crossings, and inadequate coordination among states to ensure an efficient rail system that will facilitate rail freight shipments passing through multiple states.

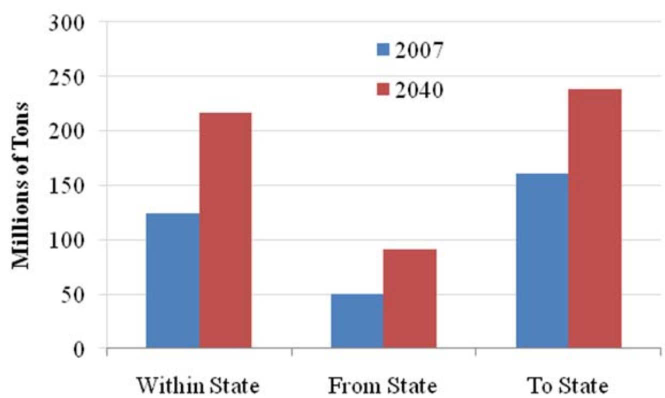
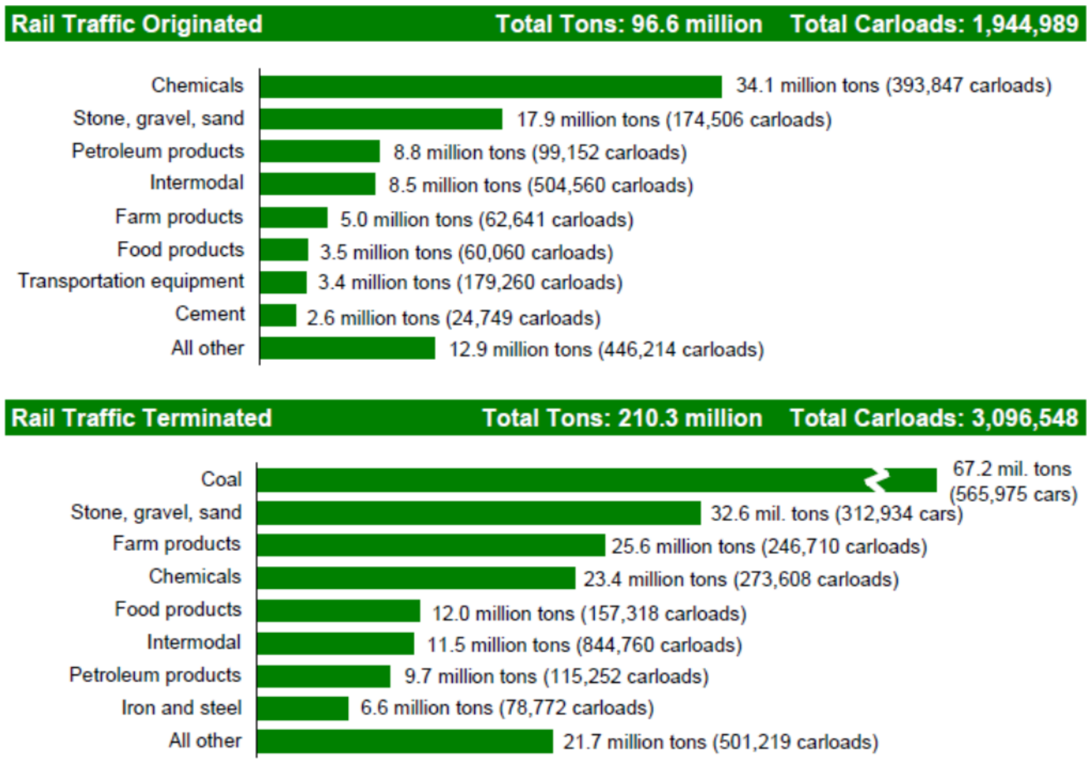


Figure 3: Rail Tonnage Moved in Texas (Millions of Tons)

Figure 4 illustrates current major commodities that originated and terminated in Texas in 2008. As is evident from Figure 4, 35% of the rail tonnage originating in Texas in 2008 was chemicals, 18% was stone, gravel, and sand, 9% was petroleum products, and 9% was intermodal traffic. In

[10] These three Class I railroads operated on 12,180 (81%) of the state's total track miles in 2008, including trackage rights.

terms of rail tonnage terminating in Texas, 32% was coal, 16% was stone, gravel, and sand, 12% was farm products, and 11% was chemicals (AAR, 2010).



Source: AAR, 2010

Figure 4: Rail Commodities Originating and Terminating in Texas (2008)

Texas's Marine Ports

Marine ports, which connect with natural and artificial waterways, serve as entry and departure points for international trade. Texas is home to 9 of the nation's top 100 marine ports when accounting for cargo volume. Texas has more than 970 wharves, piers, and docks for handling freight located on 271 miles of deep-draft channels and 750 miles of shallow-draft channels. The Port of Houston, Texas's largest port, ranked second in terms of total trade volume and first in terms of international trade volume in the U.S. (American Association of Port Authorities, 2007). Table 5 illustrates the tonnage handled by Texas's deep-draft ports in 1990 and 2008.

Table 5: Tonnage Handled by Texas Deep-Draft Ports, 1990–2008

Port	**1990**	**2008**	**% Change 1990–2008**
Beaumont	26,729,000	69,483,539	160
Brownsville	1,372,000	5,669,445	313
Corpus Christi	60,165,000	76,786,173	28
Freeport	14,526,000	29,842,295	105
Galveston	9,620,000	9,781,368	2
Houston	126,178,000	212,207,921	68

Port	1990	2008	% Change 1990–2008
Port Arthur	30,681,000	31,752,742	3
Port Lavaca Point Comfort	5,097,000	10,317,614	102
Port of Orange	709,000	676,735	-5
Texas City	48,052,000	52,606,030	9

Source: U.S. Corps of Engineers Waterborne Commerce Statistics Center

Texas's ports are primarily bulk cargo ports, transporting commodities such as, dry and liquid bulk, chemicals, petroleum, grains, and forest products. Only the Ports of Houston, Freeport, and Galveston handle containerized cargo. Several Texas ports, including the Ports of Beaumont and Corpus Christi, however, move a considerable amount of military cargo (Kruse et al., 2007). Texas's seaports contribute substantially to the state's economic vitality and the flow of goods.

Table 6 shows the projected increase in tonnage for Texas ports and Table 7 shows the anticipated increase in intermodal containers moved through Texas's deep water ports given three growth scenarios. As is evident from Tables 6 and 7, both tonnage and the number of containers handled by Texas ports are anticipated to increase significantly between 2008 and 2035, i.e., on average 63 and 359%, respectively.

Table 6: General Cargo Forecasts for Largest Texas Ports by Tonnage, 2008–2035

Port	2008 (tons)	2035 (tons)			Percent Change		
		Low-Growth	High-Growth	Average	Low-Growth	High-Growth	Average
Beaumont	81,383,531	128,292,792	131,742,692	130,017,742	57.6%	61.9%	59.8%
Brownsville	5,306,311	10,066,802	10,894,183	10,480,493	89.7%	105.3%	97.5%
Corpus Christi	85,859,440	128,342,706	185,781,802	157,062,254	49.5%	116.4%	82.9%
Freeport	36,000,000	53,812,806	58,276,372	56,044,589	49.5%	61.9%	55.7%
Galveston	5,911,882	8,837,082	11,215,654	10,026,368	49.5%	89.7%	69.6%
Houston	225,000,000	354,689,431	364,227,325	359,458,378	57.6%	61.9%	59.8%
Orange	681,982	1,019,427	1,260,129	1,139,778	49.5%	84.8%	67.1%
Port Arthur	29,261,601	43,740,246	47,368,332	45,554,289	49.5%	61.9%	55.7%
Port Lavaca-Point Comfort	4,600,000	6,876,081	7,446,425	7,161,253	49.5%	61.9%	55.7%
Texas City	53,953,540	80,649,761	87,339,349	83,994,555	49.5%	61.9%	55.7%
Victoria	3,035,978	4,538,180	4,902,769	4,720,475	49.5%	61.5%	55.5%
Total	**530,994,265**	**820,865,315**	**910,455,032**	**865,660,174**	**54.6%**	**71.5%**	**63.0%**

* The 2008 data shown in Table 6 differs from the 2008 data shown in Table 7, because the Cambridge Systematics (CS) report used different baseline 2008 data for their forecasts. For the Ports of Beaumont, Orange, and Port Arthur, CS used 2007 American Association of Port Authorities (AAPA) tonnage data only. For the rest of the ports, CS used data reported by the ports for CY 2008, which is different from the 2008 data reported by the AAPA and the Corps.

Source: Cambridge Systematics, Inc., 2009

Table 7: Forecast Container Increases at Texas Ports (in TEUs)

Port	2008	2035			Percent		
		Low-Growth	High-Growth	Average	Low-Growth	High-Growth	Average
Beaumont	3,280	4,407	4,407	4,407	34.36%	34.36%	34.36%
Brownsville	0	2,658	2,658	2,658	N/A	N/A	N/A
Corpus Christi	0	856,538	1,064,096	960,317	N/A	N/A	N/A
Freeport	71,900	800,000	800,000	800,000	1012.66 %	1012.66 %	1012.66%
Galveston	8,666	20,822	45,104	32,963	140.28%	420.47%	280.37%
Houston	1,794,309	4,311,277	9,338,893	6,825,085	140.28%	420.47%	280.37%
Orange	0	4,681	4,681	4,681	N/A	N/A	N/A
Port Arthur	170	408	885	647	140.28%	420.47%	280.37%
Total	**1,878,325**	**6,000,792**	**11,260,724**	**8,630,758**	**219.48%**	**499.51%**	**359.49%**

Source: Cambridge Systematics, Inc., 2009

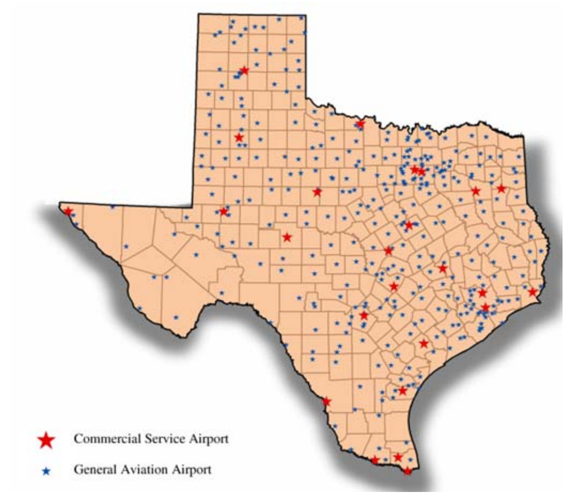
Texas ports, rail lines, and highway corridors are anticipated to be significantly impacted by the Panama Canal expansion expected to be completed and operational in 2014. In this regard, the Port of Houston will likely be the most impacted because of its partnership with the Panama Canal Authority that aims to increase trade and because it is the primary container port along the Texas coast. Currently, only Port Freeport has sufficient draft to handle the larger, post-Panamax ships[11] expected to travel through the expanded Panama Canal.

Increased waterborne trade raises concerns about ports being capable of handling increasingly larger ships, landside docks not providing sufficient access to an increased volume of ships, and dray operations[12] not being able to keep up with the extra demand (AASHTO, 2007a). Environmental and community constraints also often limit port infrastructure development, adding to the challenge.

[11] A post-Panamax containership can be up to 366 m (1,200 ft) long and 49 m (160 ft) wide and have a maximum 15-m (50-ft) draft with capacity of up to 12,000 TEUs (Panama Canal Authority, Proposal for the Expansion of the Panama Canal: Third Set of Locks Project, April 24, 2006)

[12] Freight is primarily transported to and from these ports by truck, although a few direct rail connections are in place to the Turning Basin and Barbours Cut Terminals at the Port of Houston and the Port of Corpus Christi.

Texas's Airports



Source: Wilbur Smith Associates, 2006

Figure 5: Texas's Airports

Texas is home to more than 400 international, municipal, regional, county, and other smaller local airports (see Figure 5). Of these 400 airports, 25 are classified as commercial service airports and 266 are considered general aviation airports (Wilbur Smith Associates, 2006). Texas's economy depends on its airport infrastructure to facilitate trade and the economic prosperity of the state. Nine of Texas's airports[13] qualify as "cargo" airports because they land more than 100 million pounds of freight per year. These airports include the eight international commercial service airports in Dallas/Fort Worth, Houston, San Antonio, Austin, El Paso, Laredo, Harlingen, and Lubbock (Federal Aviation Administration, 2007). Texas's only dedicated cargo airport, Alliance Airport, opened in 1989 and is located in the Alliance Texas Logistics Park in Fort Worth. Port San Antonio's Kelly Field (SKF) has an 11,500 foot (3,505 meter) runway that can handle all heavy lift aircraft, and can be served by both truck and rail. The airfield is operated under a joint use agreement with Lackland Air Force Base (Port of San Antonio, 2010).

Air freight tends to be very high value. In Texas, the 0.03% market share (approximately 0.7 million tons) by weight of air and air and truck shipments represented 4% of the market share by value in 2007. Figure 6 illustrates the value of air and air and truck shipments in terms of millions of dollars that were shipped within, from, and to the state in 2007 and the anticipated air and air and truck values that will be shipped by 2040. By 2040, the air tonnage moved within, to, and from the state will approach an estimated 2.4 million tons, translating into an increase in the value of these shipments from approximately \$88 billion in 2007 to \$339 billion in 2040 (FHWA, 2010).

[13] The remaining commercial service airports are Abilene Regional, Rick Husband Amarillo International, Southeast Texas Regional, Brownsville/South Padre Island International, Easterwood Field, Corpus Christi International, Dallas Love Field, Killeen-Fort Hood Regional, William P. Hobby, East Texas Regional, McAllen Miller International, San Angelo Regional/Mathis Field, Tyler Pounds Field, Victoria Regional, Waco Regional, and Sheppard Air Force Base/Wichita Falls Municipal. Although these commercial service airports also handle freight destined for the region or local area, the volume of freight handled at these airports is not adequate to allow their classification as cargo airports. Data is not readily available on the volume or value of freight handled at the general aviation airports, but it is generally believed that freight movements to these airports are limited to package deliveries (Personal Communication with TxDOT Aviation Division).

Because of the types of cargo moved by air (e.g., high value electronics) and the design of air cargo containers, trucking tends to be the preferred mode due to time considerations and flexibility in accommodating different load sizes. Uncongested landside access to airports will thus become even more important in the future. Table 8 illustrates the importance of good highway access and the truck mode to airports. As shown, most of Texas's air cargo airports are located within 5 miles of a U.S. Interstate highway and most airports—for which information were available—have truck terminals onsite or nearby. Freight forwarder warehouses and distribution facilities are also usually clustered in close proximity to airports.

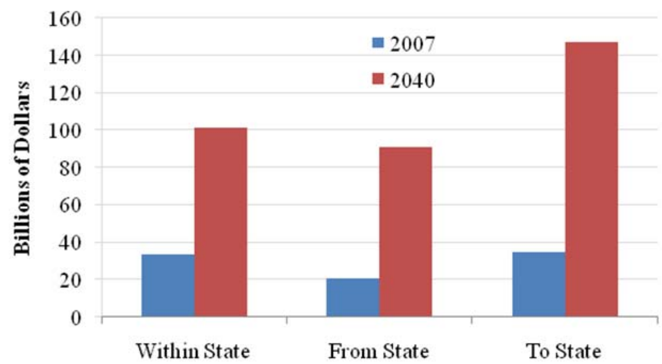


Figure 6: Value of Air and Air and Truck Shipments at Texas Airports ($ Billions)

Table 8: Distance between Texas Airports and Rail, Interstate, and Truck Terminal Facilities

Airport	Distance to Nearest		
	Rail Terminal	**Interstate Highway**	**Truck Terminal**
Austin-Bergstrom International	50	5	2
Brownsville/South Padre Island	2	4	Onsite
Dallas/Ft Worth International	30	1	Onsite
El Paso International	6	2	NA
Fort Worth Alliance	3	2	NA
Houston	4	6	20
Laredo International	3	onsite	NA
San Antonio International	5	1	2
Valley International	3	2	3

Source: Air Cargo World, 2007

Truck freight movement[14] to and from airports is also one of the few types of freight traveling during peak traffic hours (Hall, 2002), thus interacting with commuter and automobile traffic. This type of freight movement aggravates congestion and often creates bottlenecks when automobile and freight trucks share highways and access roads serving airports.

Inland Ports

Texas's most significant inland port is the Alliance Texas Logistics Park, a 17,000-acre master-planned intermodal facility. The large industrial park has air, rail (i.e., BNSF Intermodal Facility), and truck service (with access to both IH 35 and FM 156) and is located 15 miles from Fort

[14] This report separates the air freight industry into five categories of carriers: integrated freight, non-integrated freight, passenger/freight, postal, and freight forwarders (Hall, 2002).

Worth and Dallas. The inland port houses numerous developments, including a business park, a technology complex, and a 1,500-acre distribution center. The business park is home to over 140 companies. The 735-acre intermodal yard, operated by BNSF, was relocated from Dallas to Alliance. Alliance Airport is a 7,500-acre dedicated industrial airport, the first of its kind in the Western Hemisphere. The airport handles air cargo, corporate aviation, and military operations. The airport is also home to FedEx's Southwest Regional Sorting Hub, American Airlines aircraft maintenance center, and the Federal Aviation Administration's (FAA) Flight Standards District Office. Alliance Texas Logistics Park is a very successful planned intermodal port. From 1990 to 2006, it has generated $31.3 billion in economic activity and created almost 28,000 jobs (Alliance Texas, 2007).

Texas's Pipelines

Texas's pipeline infrastructure is vital to the transportation of fuel and chemicals in the state. Texas's total pipeline infrastructure totals nearly 200,000 miles, representing nearly 17% of all hydrocarbon pipeline mileage in the U.S. (Roop et al., 2000). Products moved by pipeline in Texas typically include crude oil, natural gas, liquefied petroleum, refined products, and petrochemicals. These products are transferred from pipeline system tanks to other storage tanks or refinery tanks; products are then transferred to surface and water transportation modes, including tanker trucks, rail tank cars, or barges or tankers, at terminal or refinery facilities. Figure 7 illustrates pipeline shipments in terms of millions of tons that were shipped within, from, and to the state in 2007 and the anticipated tonnage by 2040. Between 2007 and 2040, it is estimated that pipeline tonnage within the state will increase by 43%, tonnage moved from the state will increase by 17%, and tonnage moved to the state will decrease by 5% (FHWA, 2010).

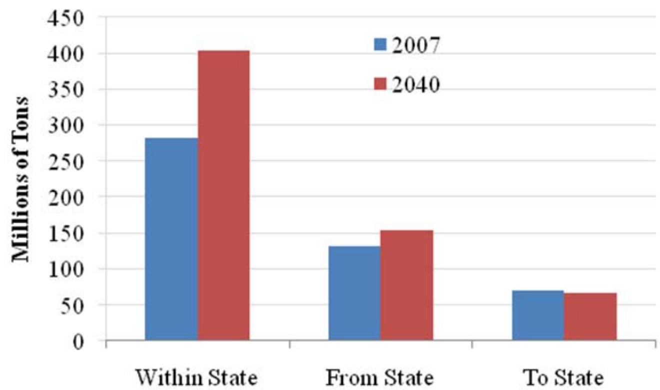
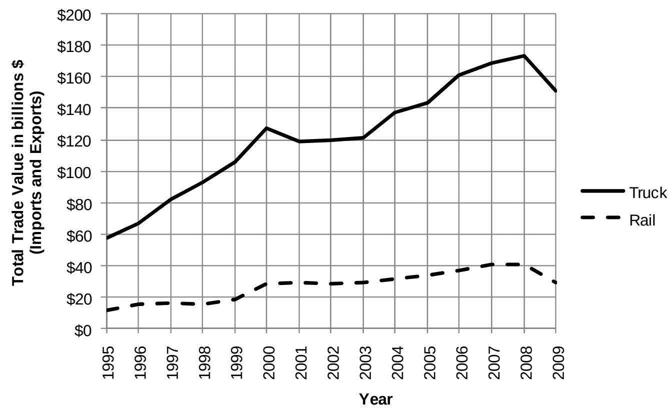


Figure 7: 2007 and 2040 Texas Shipments by Pipeline

Border Ports of Entry

When NAFTA went into effect on January 1, 1994, it enhanced already increasing trade levels between the U.S. and Mexico. Between 1995 and 2000, total U.S. surface trade with Mexico increased from $96.7 billion to $210.6 billion—a 118% increase. Between 2000 and 2009, U.S. surface trade with Mexico continued to increase to $251 billion in 2009. The increase in overall surface trade was led by imports from Mexico.

With its extensive transportation network and connections with Mexico, Texas has become the hub of international trade between the U.S. and Mexico. Eleven land ports of entry are sited along the border between Texas and Mexico: El Paso, Fabens, Presidio, Del Rio, Eagle Pass, Laredo, Roma, Rio Grande City, Hidalgo, Progreso, and Brownsville. Trucks are the dominant mode of transportation for U.S. trade with Mexico. More than 80% of the total value of imports and exports were transported across the border by truck and less than 20% by rail since 1995 (see Figure 8).



Source: Bureau of Transportation Statistics, Transborder Freight Data

Figure 8: Total U.S.–Mexico Trade Value by Rail and Truck at Texas Border Crossings

Rail Crossings

Five of the seven locations where rail crosses the U.S.–Mexico border are in Texas. The international rail gateways in Texas are in Brownsville, Laredo, Eagle Pass, Presidio, and El Paso. Each of these five gateways has one single-track bridge to transport rail freight over the Rio Grande with the exception of El Paso, which has two rail bridges. The two Mexican railroads connecting to the Texas gateways are Ferrocarril Mexicano (Ferromex) and Kansas City Southern de Mexico (KCSM). Table 9 provides a list of the connecting U.S. railroads at each border crossing and also includes the TxDOT district in which crossings are located.

Table 9: Texas–Mexico Border Gateways and Railroad Connections

District	Border Crossing		Connecting Railroads	
	Texas	Mexico	Texas	Mexico
Pharr	Brownsville	Matamoros	UP*	KCSM
Laredo	Laredo	Nuevo Laredo	UP, KCS	KCSM
	Eagle Pass	Piedras Negras	UP, **BNSF	Ferromex
El Paso	Presidio	Ojinaga	TXPF	Ferromex
	El Paso	Ciudad Juarez	UP, BNSF	Ferromex

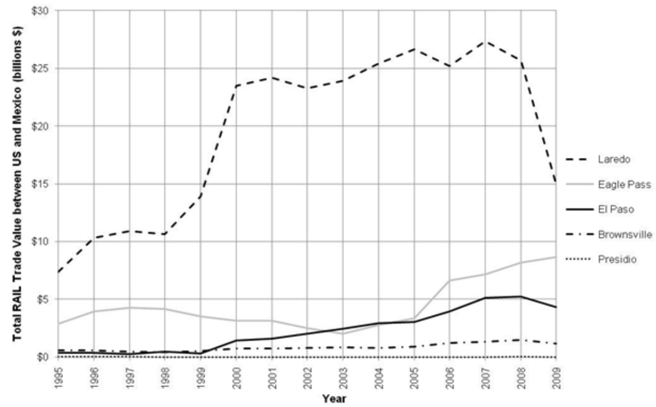
*BNSF does not have trackage rights to connect with KCSM, but does have trackage rights with UP to access the Port of Brownsville.

**Through trackage rights with UP.

Source: Texas Transportation Institute, 2001 (updated to reflect the KCS acquisition of TFM & TexMex)

Of the five Texas border rail crossings, Laredo has consistently been ranked first in terms of total trade value crossing the U.S.–Mexico border (see Figure 9). In 2009, Laredo accounted for 51.4% of the total value of U.S.–Mexico imports and exports crossing the Texas border by rail. In the same year, Eagle Pass ranked second, with 29.8% of the total value, followed by El Paso (14.8%), and Brownsville (3.9%).

Figure 10 illustrates the number of trains that crossed the Texas–Mexico border between 2000 and 2009 (North American Transborder Freight Data, 2010). In 2009, 6,406 trains crossed the Texas–Mexico border. From Figure 10 it is evident that the number of trains entering Texas from Mexico at Laredo and El Paso generally increased between 1998 and 2007, after which a steep decline is evident that can partly be attributed to the economic recession. The exception is Eagle Pass, which experienced an increase in train crossings between 2007 and 2009. Rail is of critical importance for the movement of vehicles and vehicle parts at the Laredo, El Paso, and Eagle Pass ports of entry.



Source: Bureau of Transportation Statistics, Transborder Freight Data

Figure 9: Total U.S.–Mexico Trade Value by Texas Rail Border Crossing

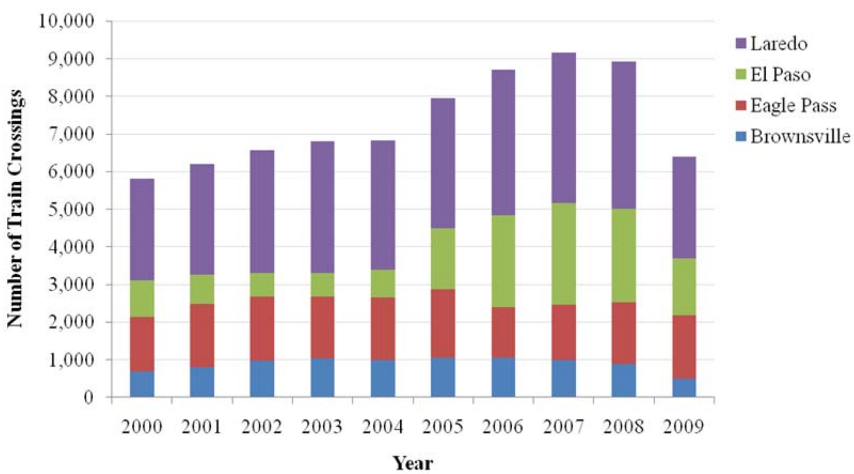
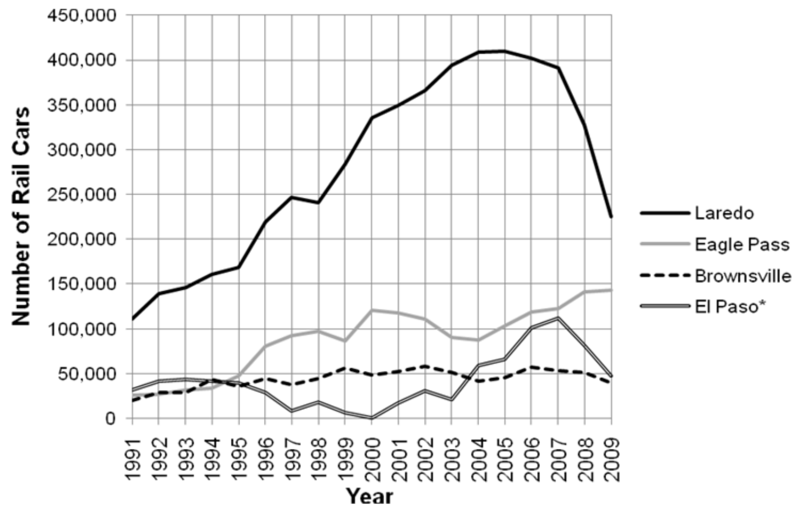


Figure 10: Number of Trains Crossing Texas–Mexico Border

Finally, Figure 11 illustrates the total loaded and empty rail cars crossing the Texas–Mexico border between 1991 and 2009 by border crossing. Figure 11 shows that the total loaded and empty rail cars crossing at El Paso, Eagle Pass, Laredo, and Brownsville more than doubled between 1994 and 2000 and continued to trend upward until 2006. Rail traffic at Laredo accounted for the majority of northbound and southbound rail car crossings. For example, between 1993 and 2000 the volume of loaded rail cars handled in Laredo increased by 130% and continued to increase until 2005. Figure 11 also illustrates the general decline in rail car crossings after 2006—the exception being Eagle Pass. At Eagle Pass - which is seen as a substitute for Laredo due to its geographic proximity - rail car volumes actually increased subsequent to 2007 (Texas Center for Border Economic and Enterprise Development: Rail Border Crossings, ND).



Notes: The asterisk (*) indicates that the data for El Paso is incomplete after 1999 and completely missing in 2000. The El Paso loaded rail car count after 2000 includes only the northbound counts available from the U.S. Customs Service and does not include any southbound counts.

Source: Texas A&M International University, Laredo, Texas

Figure 11: Total Loaded and Empty Rail Cars at Specific Texas Border Crossings, 1991–2009

Truck Crossings

Truck crossings are available at only 10 of the 16[15] U.S.–Mexico crossing locations in Texas: Brownsville, Del Rio, Eagle Pass, El Paso, Fabens, Hidalgo, Laredo, Presidio, Progreso, Rio Grande City, and Roma. Table 10 shows the total number of bridges and truck crossing bridges at each gateway.

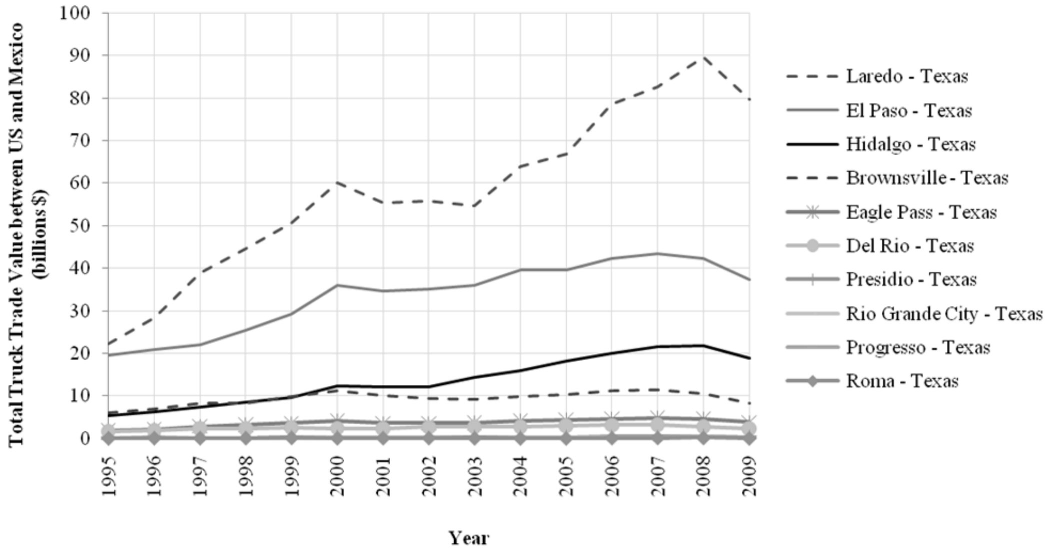
Table 10: Texas–Mexico Border Gateways and Commercial Truck Connections

Area	Number of Bridges	Truck Crossing Bridges
Brownsville	4	1
Del Rio	1	1
Eagle Pass	2	1
El Paso	4	2
Pharr[16]	1	1
Laredo	4	2
Presidio	1	1
Progreso	1	1
Rio Grande City	1	1
Roma	1	1

[15] Other identified bridge locations include Fabens, Falcon Lake, Fort Hancock, Lake Amistad, Los Ebanos, and McAllen-Hidalgo.

[16] Beginning September 1, 1996, all northbound commercial vehicles were directed to this bridge from the McAllen-Hidalgo-Reynosa Bridge. Southbound commercial vehicles are permitted to use either bridge to enter Mexico.

Laredo has consistently been ranked first in terms of total trade value crossing the U.S.–Mexico border (see Figure 12) since 1995. In 2009, Laredo accounted for 53% of the total value of U.S.–Mexico imports and exports crossing the Texas border by truck. In the same year, El Paso ranked second, with 25% of the total value, followed by Hidalgo (12%), and Brownsville (5%).



Source: Bureau of Transportation Statistics Border Crossing/Entry Data, 2010

Figure 12: Total U.S.–Mexico Trade Value by Texas Truck Border Crossing

In 2009, approximately 2.85 million trucks crossed the Texas–Mexico border into the U.S. Figure 13 illustrates the total number of trucks that crossed the Texas–Mexico border between 2000 and 2009 (North American Transborder Freight Data, 2010). The majority of the trade shipments that cross at El Paso and Laredo by truck move on the three primary highway corridors—i.e., IH 10, IH 35, and IH 20—that link these major border crossings with major inland consumption areas (e.g., Dallas/Fort Worth in Texas).

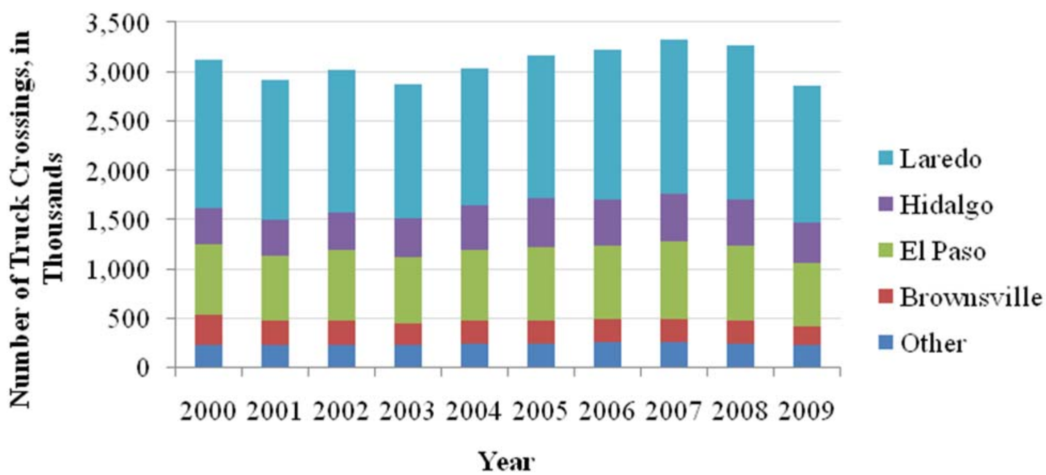


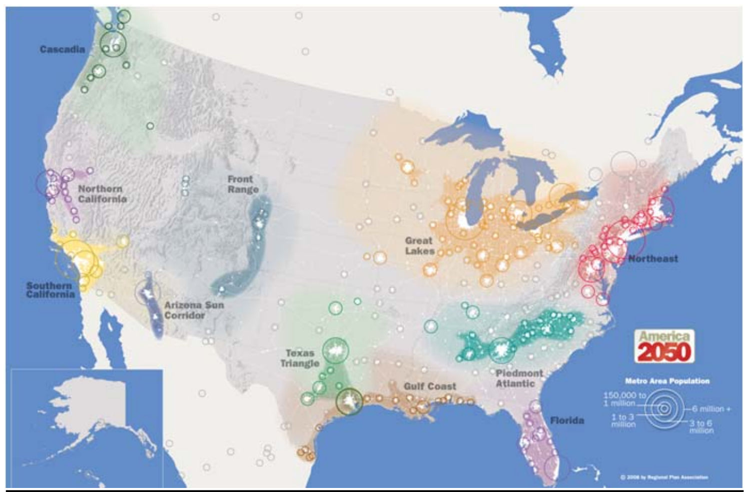
Figure 13: Number of Trucks Crossing Texas–Mexico Border in U.S.

From Figure 13, it is evident that the total number of trucks crossing the Texas–Mexico border generally increased after the inception of NAFTA. The impact of the economic recession is also evident in the decline in the number of trucks after 2007.

Public Policy and Planning Framework Impacting Freight Planning

Megaregions and Freight Planning

Megaregions originate from the work of the French geographer Jean Gottman, who described a new urban form – Megalopolis – to characterize the interconnected cities along the northeastern seaboard of the United States, from Boston to Washington, D.C. There are between 8 – 11 Megaregions within the U.S. that researchers and planning groups have identified over the past decade. Texas has one Megaregion situated within its borders known as the *Texas Triangle*, and another that forms the western locus of the *Gulf Coast* Megaregion that runs along the Gulf of Mexico to Alabama. One set of researchers have also identified a Megaregion that runs the I-35 corridor from Laredo to Kansas City.



Source: America 2050

Figure 14: U.S. Megaregions

In the past decade the Megaregion saw a renaissance, and has taken on new dimensions as planners began to look at how Megaregions were impacting social, economic and environmental issues, and could be used as a tool to reduce some of the problems arising in large urban megapolitan areas of the U.S, such as congestion, air quality attainment, water rights, and development disparity. Megaregional planning offers an opportunity – or some could say a mechanism – to look at transportation issues through a strategic lens with a view to developing a regionally (and inter-regionally) planned and coordinated response.

One research area is how a Megaregion focus could be of use to the planner examining the impacts on freight. Three main rationales are driving this (i) freight knows no boundaries or borders and relies on a network that crosses multiple jurisdictions, networks and regions (ii) in some areas the Megaregions overlay critical freight hubs and major freight corridors, and (iii) maintaining our current level of efficiency in freight requires strategic network planning and a regional funding approach to ensure that:

- long-haul and short-haul elements of the supply chain are effectively integrated;
- local planning decisions that impact the entire network consider the bigger-picture; and
- freight funding decisions can be coordinated and therefore maximized.

In Texas, freight plays a substantial role in the economic health of the state. The Dallas-Ft. Worth Metroplex is a large air and rail freight hub, the Port of Houston is the second busiest maritime port in the U.S. by overall tonnage handled, and Laredo is the largest land-border crossing for truck and rail freight on the U.S. Mexico Border. In Texas, planning for freight should be viewed as a strategic activity to enhance the economic competitiveness of the state and expand access to goods. This strategic vision for freight, however, does not exist.

Planning for transportation is one area in which the federal government has maintained a role due to interstate commerce and its pre-emption in this area. State DOTs and the MPOs/COGs are required to develop transportation plans that incorporate freight. However, the MPOs are restricted to planning within their specifically delineated areas, and the State DOTs often play a fill-type role to ensure that rural and smaller local areas are incorporated into the overall State Transportation Improvement Plan. While the city, MPO, and the state have hitherto worked as a reasonably efficient mechanism for developing the highway network and determining appropriate levels of services and funding to be allocated to each area, there are limitations to how they can conduct and implement Megaregional freight planning.

Other factors that are inescapable also play a cumulative role for the future transportation and land use planner. The U.S. is continuing to grow, with much of the new growth moving to large urban areas in the Megaregions. These Megaregion areas all need goods and services, and the demand for these goods and services is projected to continue to grow over the next 25+ years. As a result of this growth, demand for freight movement will also continue to increase. Capacity to transport freight via rail, air, water and road requires preservation as well as continued investment in our freight network to keep pace with demand. As a consequence, the ability to govern, plan and fund at the Megaregional scale will require the multitude of individual jurisdictions to compromise and work together for the better good of the Megaregion.

Greater Productivity from the Truck Fleet

When compared with other modes, trucks have seen the least improvement over the last two decades in overall efficiency. Despite better and more efficient engines, truck fuel efficiency and productivity faces a glass ceiling due to standards for maximum vehicle size and weight that have remained frozen for decades. Whatever improvements in overall engine design have been incorporated into the trucking fleet have also been adopted into trains and ships, yet only trucks have been excluded from expanding their dimensions and thereby realizing economies of scale. For a number of reasons, truck productivity must increase in the future. For instance, even if robust growth in rail capacity is assumed, rail cannot be expected to fully shoulder the burden of the growth in freight. Trucking will continue to play a vital role, yet trucking in the traditional sense is becoming more costly due to higher labor costs, more expensive trucks and higher fuel costs.

Trucks currently share the road infrastructure with smaller passenger vehicles. The close proximity of truck and passenger operations helps to explain the apprehension of policymakers in allowing an expansion in truck dimensions even when the research suggests that longer or heavier trucks are not necessarily more dangerous. Segregation of truck and passenger and truck traffic along major corridors through dedicated lanes is one potential solution that would allow for the emergence of longer trucks that could bring down labor and fuel costs on a ton-mile basis. Segregation of truck and passenger traffic also opens up new possibilities for truck automation. The concept of automation has evolved beyond the idea of trucks simply "driving themselves" to include multiple arrangements in which computers and drivers share essential functions. Furthermore, the capital costs associated with automation – using technology that already exists - would become more favorable in the context of longer combination vehicles in which each tractor is responsible for a larger payload.

Toll Roads and Trucks

The size of Texas and its centers of population required planners in the 1960s to first develop a system of high quality corridors – achieved by the 1980s – before urban metropolitan systems, including toll roads, became a prime focus. Toll roads are now playing a role in moving urban traffic, most of which is automobiles, efficiently though these have not been accepted with equanimity by all sectors of the traveling public. Some truck operators are opposed to paying for highways using tolls and appreciate the value (to them) of the current method of cost allocation[17]. Recently, the American Trucking Association stated that truckers now favored raising the tax on diesel rather than face other forms of raising revenue like tolls.

It is, however, important to acknowledge that the trucking industry is not homogenous. The trucking sector can be segmented in terms of:

- Service area, e.g., local, regional, national, and international (i.e., crossborder U.S.-Canada, U.S.-Mexico, and Canada-Mexico),
- Trip type, e.g., intra-city, inter-city, and through trips,
- Vehicle ownership, e.g., owner-operator and company truck,
- Vehicle operator, e.g., owner-operator and company employee driver[18],
- Fleet size, e.g., small (less than five trucks), medium, and large,
- For-hire or private trucking,
- Vehicle characteristics, e.g., light, medium, heavy, and specialized trucks,
- Type of trailer, e.g., dry freight, refrigerated, flatbed, liquid tank, dry hopper, auto rack, household goods, and
- Type of carrier/operation, e.g., truckload, less than truckload, parcel/express, and specialized services.

Although these segments are not mutually exclusive, it is important to recognize the different segments when delineating the factors influencing a trucking company's decision to use or avoid a toll facility. For example, the cost structure and route choices of these segments are different. Local trucker's costs could be significantly increased by congestion. A local toll bridge or tunnel could thus see a high percentage of truck users, for the following reasons: (a) the tolled facility is on the shortest, fastest route to and from the trip's end points, (b) the toll

[17] Most costs allocations show the heavy trucks are cross-subsidized by other classes to some degree. See http://www.fhwa.dot.gov/policy/otps/costallocation.htm

[18] In the case of employee drivers, a dispatcher typically makes a decision regarding routes for each trip given the policy guidance from a senior corporate officer.

charged is comparatively low compared to the incremental variable cost to operate on an alternative non-tolled route, and (c) everyone has to use the toll facility as no non-toll alternative exists. In other words, the cost of the toll does not have any competitive consequences. On the other hand, Knorring et al (2005) found that cost/benefit was a significant factor in the route selection of long haul truckers.

More generally, truckers will choose to pay a toll only if it makes business sense, i.e., the rates paid by the shipper allows the trucking company to recover the increased operating costs associated with using the toll facility or the savings in operating costs (time, fuel, etc.) exceed the additional cost imposed by the toll. Trucking companies also tend to support toll roads if the opportunity exists to use longer (and/or heavier) trucks and trailers (i.e., long combination vehicle, LCVs) on tolled facilities - thereby achieving economies of scale by operating one larger and heavier vehicle as opposed to having to make a second trip.

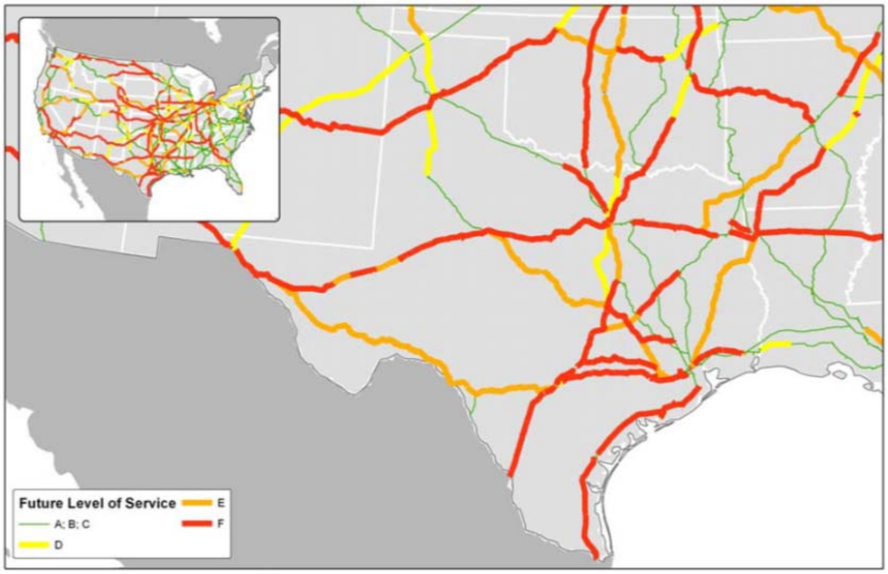
Also, discussions with carriers have revealed that in many instances truck usage of toll roads will be determined by the shipper's willingness to pay for the incremental cost of toll charges incurred. This requires a better understanding of the factors considered by other goods movement businesses (e.g., shippers, receivers, logistics companies, and brokers) in their decisions to use (in the case of private fleets) or compensate the trucking sector for using toll facilities.

Finally, an understanding of the factors and tradeoffs by goods movement businesses in their decisions to use or avoid toll roads are also critically important in anticipating these businesses' reactions to changes in tolls charged. For example, when the New Jersey Turnpike increased the toll schedule for trucks, a significant number avoided the Turnpike and diverted to U.S. Route 1. This resulted in significant congestion on the non-tolled U.S. Route 1. On other hand, six bridges in the San Francisco Bay Area increased truck tolls with no changes in truck usage of the facilities. The cost increase was furthermore "absorbed" by the truck operators without a concomitant increase in price charged to shippers and receivers.

Hence the question remains why goods movement businesses use or avoid toll facilities, what are the critical factors being considered, and what are the tradeoffs in their decision-making processes. A better understanding of these factors and tradeoffs will improve the robustness and reliability of T&R studies and assist stakeholders in anticipating the consequences of truck toll increases more effectively.

Moving Interstate Freight by Rail

Inadequate rail capacity is a growing concern in Texas. The National Rail Freight Infrastructure Capacity and Investment Study anticipated that Texas's rail level of service rating—i.e., capacity versus usage—will reduce from a concerning average "D" rating to a critical average "F" rating assuming no improvements are made (Cambridge Systematics, 2007).



Source: Association of American Railroads National Rail Freight Infrastructure Capacity and Investment Study

Figure 15: Projected Railroad Level of Service, 2035 (Without any improvements)

This finding was largely supported by the concerns expressed by freight stakeholders that participated in a serious of freight workshops in 2009/2010 as part of TxDOT Research Study 0-6297. Specifically, rail capacity concerns were expressed in the Panhandle Region. It was reported that the existing rail capacity is only able to move a third to half of the cotton containers generated in the region in a year (Lubbock Metropolitan Planning Organization, 2006). Rail capacity concerns in the region are anticipated to increase in the future as the rail demand increases for the region's growing industries—e.g., agriculture, livestock, and energy production (i.e., wind and ethanol). For example, agricultural production alone is expected to increase by 151% by 2025 (HNTB Corporation, 2008). Also, in the Central Region, freight stakeholders reported that rail congestion in Houston, Fort Worth, and El Paso impacts rail shipments out of the region, particularly during peak seasons. Freight stakeholders in the Piney Woods reported that rail congestion in Dallas Fort Worth negatively impacts shippers in the Piney Woods Region. In addition, freight stakeholders in the Central, Panhandle, and Piney Woods Regions also expressed concern about inadequate rail capacity during the harvest season. They called for the development of the region's short line railroad system to facilitate goods movement in the region.

Finally, increasing rail freight tonnage is straining capacity at rail yards in many parts of the state. For example, yard capacity is a concern at the UP railroad interchange yard at the Port of Beaumont.

If a modal shift from road to rail is thus encouraged, substantial investments will be required in Texas's rail system. A series of TxDOT funded freight studies[19] have identified approximately $4 billion in crossing closures, grade separation projects, and new rail connections needed.

[19] The rail freight studies were undertaken by HNTB Corporation and Jacobs Engineering to better understand freight movement in Texas both by truck and rail. Specifically, the goal of these studies is to:

Moving interstate freight by marine highways

The US Secretary of Transportation designated the Marine Highway network in August of 2010. The use of nomenclature analogous to the Interstate Highway System implies a clear intention to create a framework under which domestic maritime shipments could seamlessly complement truck and rail corridors in handling future freight flows. Given the ever increasing cost of maintaining road and rail infrastructure and the large amount of land required to construct new corridors to relieve congestion, the potential development of marine highway corridors that would require comparatively little infrastructure investment holds a strong appeal.[20] Nevertheless, recent research has shown that significant structural challenges will impede the development of a comprehensive marine highway network in the near future. While marine highway corridors do not require pavement, they do require a fleet of vessels that does not currently exist within the U.S. and is not likely to exist for some time.

Source: Marad

Figure 16: America's Marine Highway Corridors

The principal requirements for establishing viable corridors are, in increasing order of complexity, 1) corridor designation, 2) refinement of port infrastructure, 3) shipper, coordination, and 4) commissioning and construction of vessels. The US has clearly made progress in the short term goal of determining the most promising options for overwater shipment. Within Texas, joint planning efforts, including strategies for involving shippers, are already underway in coordination with the other states on the M-10 corridor.[21] The US has also made certain strategic investments in ports that may aid marine highway development, yet until shipper coordination and a framework for vessel construction is established it is unlikely

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- inventory existing rail systems;
- conduct a study of existing operations;
- identify freight constraints;
- identify safety issues with rail interactions and roadways;
- develop alternatives for improvements; and
- model these alternatives and complete cost-benefit and economic analyses for these alternatives.

To date, studies have been completed in San Antonio, Houston, West Texas, East Texas, Corpus Christi/Yoakum, and Dallas/Ft. Worth. Phase I of the Rio Grande Valley/Laredo study is also complete, and the Phase I study for El Paso has recently started. The full reports for these studies are available on the TxDOT website (www.txdot.gov).

[20] America's Marine Highway, Report to Congress, April 2011. http://www.marad.dot.gov/documents/Americas_Marine_Highway-Report_to_Congress-April_2011.pdf

[21] "Gulf Regional Marine Highway Strategy Development Roundtable Discussion, Draft Agenda," Isla Grand Beach Resort, South Padre Island, Texas, Tuesday, April 26, 2011

that the full potential of marine highways will be realized. At some point, however, it is likely that the inherent advantages of increased domestic marine shipping on underutilized corridors will become strong enough to overwhelm the policy inertia that has thus far stymied their development.

One of the most logical areas for marine highway to establish a foothold is in the hazardous materials market. The movement of HAZMAT in the United States is becoming increasingly problematic due to growing concentrations of population around rail corridors. Marine Highways have the potential to greatly lower the exposure of the population to risk and become a preferred alternative heavily trafficked HAZMAT routes. The transport of overweight containers is another key growth area for domestic shipping, but again the vessel infrastructure for such shipments is currently lacking. The time is right for Texas agencies that have an interest in sustainable freight to formulate a strategy as to how Texas intends to use its marine highway assets in the future, along with a realistic timeline for deployment.

Summary

The team recommends consideration of three levels of freight studies based on timing and complexity. The first are short term, small scale studies which can focus on specific elements of the topic area that most critically impact TxDOT. Typically, these will be closely linked to recent TxDOT sponsored research where teams are still available to provide inputs and data. The second are studies that illuminate issues of growing concern during the period 2011 and 2025/30. The final group are those which will be game changers beyond 2030 and worthy of consideration now so that TxDOT can transition its long term mission and strategy efficiently. Specific topics for consideration follow:

1. *Create a vision for the Texas Freight Transportation Infrastructure of 2050 considering key drivers and given a multi-stakeholder dialogue.* A better understanding is needed of what will drive freight transportation systems four decades from now - i.e., what commodities will be moved, how much will be moved, how will they be moved, and where will they be moved. Key drivers of change that could impact the vision for Texas's Freight Transportation Infrastructure include both macro and micro drivers. Macro drivers typically influence the volumes of goods moved and include drivers such as global economic growth, the political environment, and technological development. Micro drivers affect specific dimensions of freight transportation and include energy costs, environmental policies, supply chain structures, industry structures, and governance. Given various assumptions about how these drivers will interact to impact freight transportation under different scenarios will allow Texas to create an informed vision for the Texas Freight Transportation Infrastructure of 2050.

2. The cost of transportation can have a substantial impact on the competitiveness of major export industries in Texas, whether these industries export to foreign countries or to one of the U.S. states. The price of transportation (i.e., the freight rate charged) is the cost of providing the transportation service, but the more generalized cost of transportation reflects the impacts of legislation (e.g., safety regulations at ports and airports), regulations,

or policies, border crossing issues, unreliability in the transportation system, damage and pilfering en route, lengthy transit times, etc. *It is thus recommended that the role of transportation in the logistics chains of a sample of Texas's major industries be explored.* This study will describe the general logistic chains for a number of Texas's major industries and identify the role of transportation in the logistics chain. The study will examine a number of options for reducing the generalized costs of transportation in the logistics chains, relating to policies, transportation legislation and regulations, infrastructure, and new technologies that can be adopted to increase the efficiency of Texas's transportation system. These options have the potential to decrease transportation costs and enhance the competitiveness of Texas's major industries.

3. In Texas, freight movements have and are expected to continue to increase substantially due to sustained and anticipated economic and population growth combined with Texas's optimal location along critical trade corridors. The forecasts of freight demand included in this paper clearly demonstrate that freight transportation by all modes will continue to grow in Texas. Good freight planning will thus become critical to ensure that Texas's infrastructure can accommodate the estimated increases in freight demand. *It is thus recommended that a detailed freight plan be developed for Texas that includes the role of freight in serving large urban areas in the megaregions.*

4. A number of states have benefitted from engaging the private sector as stakeholders (i.e., Freight Advisory Committee/Stakeholder Working Group) when conducting statewide freight planning. The potential role of a Freight Advisory Committee/Stakeholder Working Group can be to (a) assist an agency in identifying freight transportation needs, (b) provide input on freight transportation policies and the development of freight performance measures, (c) assist in the identification of funding opportunities and partnerships between the public and private sectors, (d) assist in the prioritization of freight concerns, (e) communicate the importance of freight investments to the public, elected officials and other public agencies, and (f) recommend freight research areas and needs. During a recently completed TxDOT research study, 35 companies and agencies expressed an interest in working with TxDOT in developing and implementing a Freight Stakeholder Working Group for Texas. It is thus recommended that *the mission, purpose, objectives, and mandate of a Texas Freight Stakeholder Working Group be explored during a meeting of interested freight stakeholders*. During such a meeting, a FHWA freight peer exchange can be hosted that would allow other state DOTs that have an established Freight Advisory Committee or Stakeholder Group to share, their mandates, roles, and objectives, as well as successes, benefits, and challenges that have been experienced. At the conclusion of the peer exchange, attending stakeholders can work together with TxDOT to decide on the concept for Texas, as well as the mandate, role, and objectives of a Texas Working Group.

5. A study to be undertaken using the 5974 truck operating cost model and calibrated using contacts at H-E-B, Frito Lay and PepsiCo to examine a series of heavy truck, truck-load (TL) operation demand curves for SH 130. These would estimate the breakeven toll fees for various levels of congestion on IH-35 and gather information on how information on congestion and accident data levels which would trigger an advantage in using SH 130 could be sent to the drivers using IH-35.

6. A one year study to establish the bridge costs required to allow more productive trucks to use key interstate corridors in Texas. This would follow up on the final report of study 0-6095 where the bridge costs were estimated from moment and fatigue based mechanisms using BRINSAP data. The team would examine each structure and determine the actual strengthening required. In other states, such field work reduces overall costs because not all bridges have to be replaced. These data would then form the base for calculating the marginal cost of the permits for heavier trucks and so meet the conditions of equity.

Texas Department of Transportation

Providing safe, effective, and efficient movement of people and goods.

Strategic Research Program – Research Brief

Strategic Directions for Performance Management in TxDOT: Customer Satisfaction as a Key Driver of Success

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1 June 2011

Strategic Research Program Purpose

The Texas Transportation Commission established the Texas Department of Transportation (TxDOT) Strategic Research Program in 2011 to assist the department with its number-one goal: preparing for the future. This series of research briefs is intended to identify and frame transportation challenges Texas will face over the next 10 to 30 years. In support of that goal, the briefs attempt to spur discussion within and outside of TxDOT to address issues that TxDOT's stakeholders, interest groups, the Texas Legislature, TxDOT Administration, or the Transportation Commission foresee affecting the efficiency and viability of the state's transportation system.

Using current literature, interviews, and other sources, briefs are meant to provide the reader with an overview of the subject and emphasize the strategic elements of a topic that may need further development, either focused research or internal TxDOT actions. The briefs themselves are not intended as a detailed examination of current or planned TxDOT activity.

This research brief takes a holistic look at performance measurement (PM), both in general and transportation specific, and identifies areas for further, more detailed analysis. In particular, it focuses on opportunities to develop a more comprehensive customer satisfaction management program, which research has identified as one of the key avenues for potential improvement.

Strategic Directions for Performance Management in TxDOT: Customer Satisfaction as a Key Driver of Success

INTRODUCTION

Imagine driving down the highway in a car without a working gas gauge or speedometer. You might find your car stalled by the side of the road or see the blinking lights of the highway patrol appear in your rearview mirror long before you reach your destination.

Now imagine driving down a major road you've never traveled before that has no lane markings, road signs, or signal lights. Even if you made it through without any sort of accident, you would certainly have difficulty figuring out where to turn to reach the location of your cousin's wedding.

While situations like these are unrealistic, if not impossible, they highlight the role performance management (PM) systems play in our everyday lives.

Just as our traffic systems have a variety of means of providing feedback to users on current performance (gas gauges and speedometers) and targets (lanes, signs, and traffic signals), organizations of many different types have designed information-based routines called PM systems to serve similar functions.

Specifically, a PM system can be used to provide increased understanding for both internal and external stakeholders regarding:

- current performance versus goals,
- areas of competitive advantage,
- opportunities to improve performance,
- priority of performance objectives among various stakeholders,
- relationships between performance measures, and
- appropriate strategies for improving performance.

Although PM systems, at least rudimentary ones, are as old as organizations themselves, PM has undergone a significant change in the last 20 years, shifting from primarily financially focused systems to holistic systems capable of identifying the interconnections between stakeholders' needs, financial performance, internal efficiency, and employee capabilities.

HOW PERFORMANCE MANAGEMENT WORKS

Since the early 1990s, interest in PM has exploded in both public- and private-sector organizations and in research institutions. Neely (1999) went so far as to call this a PM "revolution," citing facts such as the publication of 3,615 articles on PM between 1994 and 1996 (or one every five hours per business day) and the publication of one new PM book every two weeks in 1996 in the United States alone. Meanwhile, subsequent research has found no evidence that this interest is subsiding. For instance, in their study, Marr and Schiuma (2003) found over 12 million websites dedicated to PM.

Since the 1990s, interest in holistic PM has grown exponentially.

What Performance Management Frameworks Are Used?

As mentioned, one of the key factors driving this revolution is the introduction of holistic measurement frameworks, which seek to develop understanding of organizational performance beyond the traditional financial measures, and also increase understanding of relationships between categories of measures. Although many influential frameworks exist, perhaps the most widely adopted is the Balanced Scorecard (BSC), which has been cited as one of the top 15 management tools (Andersen et al., 2001) and is estimated to have been adopted by 70 percent of organizations worldwide (Rigby and Bilodeau, 2007). Introduced in 1992 by Kaplan and Norton, the BSC specifies that, in order to fully understand the way an organization operates now and where it will go in the future, the organization must measure performance in four categories:

Demonstrated benefits of PM include improved financial performance, customer satisfaction, and workforce capabilities.

However, PM implementation is challenging with an estimated 60 percent failure rate.

- Financial – What are the indicators of fiscal success to *shareholders* or other evaluators?
- Customer – How will we know if we are meeting the needs of the people who *use* our products or services?

- Internal business process – How will we know if we are operating *efficiently* in creating products or services?

- Learning and growth – How will we know if we are maintaining the ability to *innovate* in a dynamic environment?

Figure 1 displays the interrelationships between the four categories, using example measures for each category.

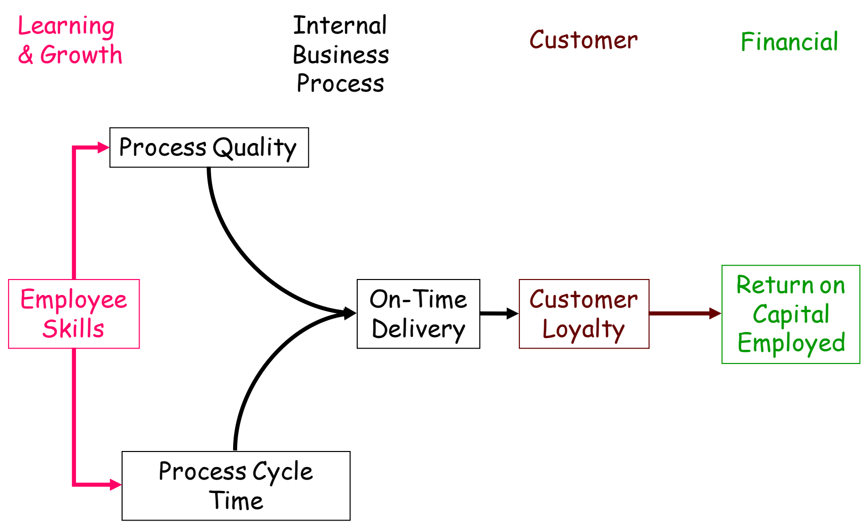

Figure 1. Relationships between BSC dimensions adapted from Kaplan and Norton, (1996), p. 66.

A similar framework was introduced by the National Cooperative Highway Research Program (NCHRP) (2010). The three categories at the far left of Figure 2, which represent key types of requirements impacting strategic planning and the development of an effective PM system, can be mapped to the BSC categories as follows.

- engineering – internal business process, and learning and growth;

- customer – customer; and

- fiscal – financial.

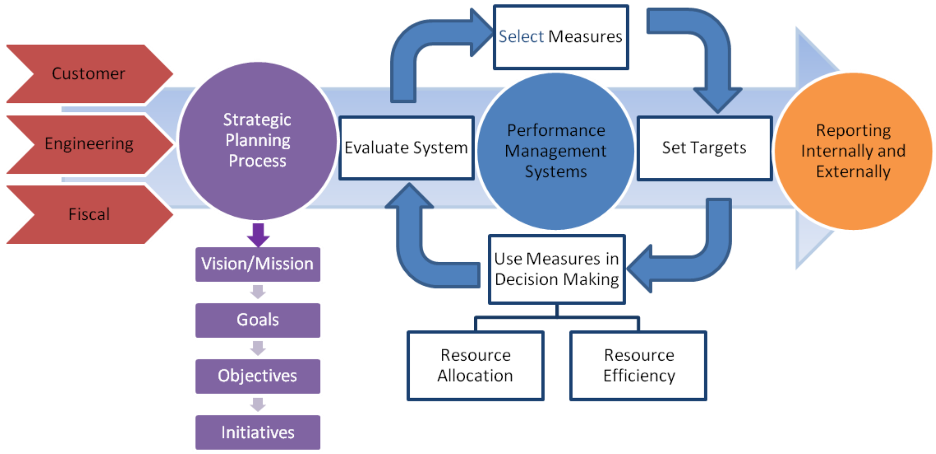

Figure 2. Performance management structure adapted from NCHRP (2010), p. 2.

What Are the Benefits of Performance Management?

In general, the literature reports a number of specific benefits from the implementation of holistic measurement systems, such as the BSC. Benefits can come in the form of increased competency in performing several key organizational functions, including:

- individual performance evaluation,
- decision making,
- problem identification,
- forecasting,
- strategic planning,
- process improvement, and
- organizational learning.

In terms of bottom-line improvement, the implementation of a holistic measurement system produces improvement in a number of key measures, such as:

- overall financial performance (Lingle and Schiemann, 1996; Scott and Tiessen, 1999; Hoque and James, 2000; Malina and Selto, 2001; Davis and Albright, 2004; Martinez and Kennerley, 2005; Crabtree and DeBusk, 2008; Iselin et al., 2008; Gimbert et al., 2010),

- industry standing (Lingle and Schiemann, 1996; Martinez and Kennerley, 2005),
- customer satisfaction (Martinez and Kennerley, 2005),
- employee learning (Martinez and Kennerley, 2005),
- employee accountability (Martinez and Kennerley, 2005),
- organizational alignment (Meekings, 2005), and
- teamwork (Martinez and Kennerley, 2005; Meekings, 2005).

What Are the Potential Downsides of Performance Management?

Despite the reported benefits from successful implementations, the literature also suggests that the failure rate for PM systems is high, estimated by one study at an average of 60 percent, with exact rates depending on the context (de Waal and Counet, 2009). Further, several negative effects have been associated with inappropriately implemented PM systems, including:

- system manipulation or "gaming," leading to suboptimization within the organization, i.e., individual workgroups maximizing their own performance at the expense of the larger organization (Propper and Wilson, 2003);
- information overload (Lipe and Salterio, 2000; Ittner et al., 2003);
- high system cost (Halachmi, 2002; Ittner et al., 2003; Marr et al., 2004; Tuomela, 2005); and
- internal resistance to change (Tuomela, 2005; Martins and de Abreu, 2006).

Thus, organizations must take extreme care in the design and deployment of PM systems to avoid potential worsening of the organizational environment. Potential implementation problems will be discussed more in a later section.

PERFORMANCE MANAGEMENT AT OTHER DEPARTMENTS OF TRANSPORTATION

The literature indicates that PM programs at departments of transportation (DOTs) specifically have also undergone a "revolution" in recent years, experiencing a surge of interest and moving to more holistically focused, balanced systems. These changes have been initiated by a range of causes, but most programs appear to currently be moving toward common points: they use a few measures for each agency function or transportation service element, they are designed to meet the needs of both internal and external audiences, and they evolve over time.

How Do They Get Started?

In many cases, the driving force for a PM system is a crisis of some form. Either the problems faced by an agency or region are too great for the funding and available project solutions, or questions arise about the competency or effectiveness of agency leadership.

"The hallmarks of performance management include establishing strategic plans, setting agency goals and objectives, identifying ways to meet them, and measuring how well they

For example, Washington State had a citizen initiative remove about one-third of state transportation revenue in 1999, and the debate surrounding that vote made it clear that the public and elected leaders were concerned about the apparent inefficiency, lack of accountability, and growing problems in a number of subject areas (Bremmer and Bryan, 2008). Virginia's Dashboard began as an internal effort to gain control over cost and scheduling problems that sapped the DOT's credibility with the General Assembly and the public (Commonwealth of Virginia, 2007). Maryland's Attainment Report (Porcari, 2009) and Florida's Key Performance Measures (Florida Department of Transportation, 2006) were developed as a way to improve the delivery of transportation products and services and to improve linkages between their long-range plan, financial plan, and employee work processes.

The Washington State DOT Accountability Office refers to "information asymmetry" as the gap between what the DOT is doing and what the public knows about what the DOT is doing. In very basic terms, PM is designed to address this gap and to aid staff improvement (Bremmer and Bryan, 2008).

How Are Measures and Targets Set?

Successful PM programs rely on strategic planning to guide their development. Although not all DOTs begin PM with a strategic plan, PM does provide support for the strategic planning process. It provides meaningful data as input to the decision-making processes and resource allocations. A DOT measurement effort may begin by calculating many measures (more than 100 is common), identifying a few that can be used with the general public and decision makers, scaling back the number of measures, and then changing the performance measures as the uses, audiences, and data sources change. The process should be continually evolving.

"The quality and specificity of the measures selected is far more important than the overall number or breadth of available

There does not appear to be a single correct way to initiate the process, but some involvement by all stakeholders at the beginning can reduce the amount of confusion and staff skepticism. Some states have spent considerable time with a range of stakeholders on this initial stage, but most have been successful with a process that begins with staff, key decision makers, and a few stakeholders. In particular, support from senior leadership, both in actions and words, is key, although it is not always required that senior leaders be actual members of the PM system design team. The small, PM system design group decides which measures satisfy a set of criteria and then embraces comments and suggestions for change as a broad set of users are provided with the data and interpretations. Criteria can include the following elements:

- Measures and data should be useful for internal processes and/or external communication about the effect of the investments and policies (do not measure only for the sake of measuring).
- A range of users should be able to explain and understand the measures (although some good measures are used solely for internal technical analyses).
- Measures evaluate both agency activity and the outcome of that activity (for instance, a measure of on-time delivery of capacity expansion projects should be accompanied by a congestion measure).

- Initially, measures should be calculated with available data or models – "start small but report now" (as new data sources are identified, they can be incorporated; very few processes have been successful with collecting data for the sole purpose of measurement programs in the initial stages).
- The process should incorporate a communications plan from the beginning; text, graphs, and easy-to-understand measures should lead the program, with data as a supporting, rather than controlling, element.

Who Is Involved in Reviewing the Measures, and How Often Are the Measures Reviewed?

Previous state DOT experience and research on private-sector performance initiatives indicate that it is important to link everyday employee tasks to some element of organizational performance and then measure the performance in a way that holds employees accountable for their contributions to overall agency performance.

The Missouri DOT (2009) used a quarterly meeting run by their executive director in an auditorium setting. The "owner" (the person responsible for performance in a particular area) describes the data and updates the performance for the measure in a way that recognizes that managers can learn from each other. This atmosphere also uses an element of peer pressure to improve performance and the data and measures. Several agencies use the concept of ownership to connect the performance to measures and data.

The North Carolina DOT may be the leading agency in this arena – each employee has an individual "Dashboard" that represents a move to a results-based performance *management* (not just measurement) system.

What Measures Are Used?

All of the state DOT PM experts indicated that the measures must relate to employee *and* agency activity, and include measures of both activity and performance. Ideally, measures are outcome oriented, meaning the measures examine the impact of decision making rather than simply the resources used on a particular activity (NCHRP, 2010). The mix of measures may include some that are purely internal (only used to manage agency activity and investments) and some that are only external (used for communication purposes), but desirably the data and measures should serve both functions. This ensures that there is a definite purpose behind the measurement effort and that the data and measures will be constantly scrutinized in a way that would not happen if the data were only used for internal reports.

The following are measures for some of the key elements. All of these measures could be calculated with data currently available to the Texas Department of Transportation (TxDOT).

- Pavement condition – The percentage of highways in good or better condition is a typical metric that is directly collected as part of TxDOT's pavement maintenance program. The measure is used at the system level, as well as at the regional and road section level. Road segment data are used to calculate the regional values and to identify sections with problems. North Carolina uses an infrastructure health index in an attempt to link several condition aspects and communicate to a nontechnical audience.

- Congestion – A variety of travel time and delay measures are used to indicate congestion levels on specific roads:

    - The travel time index and delay per capita are used at the regional level.

    - The travel time index and level-of-service (LOS) measures are used for corridor analyses in several states (LOS is used in rural corridors where congestion is not a frequent concern).

    - A frequent agency activity measure is incident clearance time.

    - Most of the congestion measures are calculated with Roadway-Highway Inventory Network (RHINO)-type data and similar procedures. They can be improved with estimates of incident congestion.

- Safety – Deaths and injury or fatality rates (e.g., crashes, injuries, or fatalities per million vehicle-miles) are used in almost every state surveyed, with before-after safety studies being a part of a few detailed crash reduction programs.

Development of performance reports is a significant use for congestion-related performance measures. The frequency of publication varies from weekly to annually, but annual reports are the most common. The linking of performance measures (more specifically, changes in them over time or their level relative to target values) and investment decisions is an established practice in infrastructure maintenance and safety improvement programs. The best example of actions taken based on congestion performance measures is the tracking of detailed output measures for incident management programs – agencies that act on these can gain greater efficiency and support for activities such as service patrol routing and schedules.

Other states have found excellent benefits by combining three elements of PM:

- using the measures to improve agency performance;
- reporting more information about that performance in ways that improve the appearance of transparency; and
- using the data, measures, and communication techniques to support requests for additional funding.

Most performance measure uses and reports are for individual agencies, but collaboration (e.g., between metropolitan planning organizations [MPOs] and DOTs) is beginning to occur more frequently.

When Are Measures Used?

Another aspect of PM is the "when" element. Regular reporting is important, but before-after studies also form a vital link between spending increases and showing the public what they are getting for their money.

Some data collection projects are likely to be one-shot efforts. Others should be ongoing. There are several reasons to repeat the same or similar studies. One reason is that many times information about a situation can be best understood when it is contrasted with a similar measure taken in a different place or a different time. For example, if we measure customer responses in multiple districts, we can understand the customers' attitudes relative to each other. If we measure customer responses in the same district but over time, then we can understand how attitudes are changing over time.

Perhaps even more important, though, is what is known as the before-after type of study. The before-after study is a type of research design where the specific impact of a public policy change can be measured. The first step is to measure customer attitudes before a policy change. After the policy change is implemented, customer attitudes are then measured again. When the data are analyzed, the results from before the policy implementation are subtracted from the results following the policy implementation. This difference represents the impact of the policy on the attitudes being measured.

Another type of research design is a time series analysis. A time series analysis examines the same data for several time periods. For example, if we want to measure customers' attitudes about TxDOT overall, then we would likely be interested in knowing this information at some regular interval (such as quarterly or annually). Once we have enough of the data in a series, we can analyze general trends, such as an increase or decrease in the satisfaction with TxDOT among its customers over time.

The frequency with which an organization conducts a customer satisfaction assessment generally depends on:

- the interval between significant changes in the factors that are being measured,
- the need for information about customers,
- the type of research design required, and
- available budget.

MEASUREMENT FRAMEWORKS SUITABLE FOR TXDOT

In this section, we first describe what TxDOT is currently doing in the realm of PM. Then, by comparing TxDOT's current PM practices to applicable frameworks from the literature (BSC and NCHRP) and the PM practices of other DOTs, we recommend changes to TxDOT's current system. In particular, we focus on the potential for TxDOT to develop a more comprehensive customer satisfaction program because research has identified this as one of the key strategic avenues for improvement.

What Is TxDOT Currently Doing?

TxDOT currently has a number of internal programs and tools to measure and track the scientific and engineered aspects of many elements of transportation. The results from these programs and tools aid TxDOT in determining current and future projects to address deficiencies, improve safety, and extend asset lifecycles. For the past few years, TxDOT has been developing a strategic policy and PM program. The department recognized the need for greater accountability and transparency as a driving force behind the program. The program has completed several activities that are informing the program and consolidating department activities. One of the first activities was to assess what other DOTs are doing in this arena, as noted above.

The department has revamped the strategic plan for 2011 through 2015 based on public input, including a comprehensive polling effort completed in 2009. The *TxDOT Tracker* and *Project Tracker* websites were developed to provide detailed information about system performance and project-specific milestones, respectively. The websites were vetted and tested through a public involvement process to assess what information is meaningful to the user. The websites have continuously been enhanced to make them more useful. Moreover, the department developed specific action items tied to the strategic plan goals and objectives.

Previous TxDOT practice required the department to submit targets and results of some performance measures to the Legislative Budget Board (LBB). This process is closely tied to the budget structure but does not necessarily reflect the department's strategic plan goals.

More recently, TxDOT developed a series of performance measures across a number of functional areas that go beyond the scientific and engineered items. Aligned with TxDOT's strategic plan, these performance measures provide a reporting mechanism for TxDOT to hold themselves accountable to the citizens of Texas.

The three types of measures that TxDOT currently uses are:

- internal,
- external, and
- legislative.

TxDOT currently reports on a total of 25 performance measures. Twenty-one of these support TxDOT's strategic goals. The other four are what the department terms external and beyond the department's immediate control, but they are important, nonetheless, because of the impact on transportation.

TxDOT is also in the process of developing a customer satisfaction program that will bring the public's priorities and expectations on certain issues into the decision-making process of the department. A guidebook, *Tell TxDOT,* outlines the various techniques identified to date for collecting public input, and the contents and logistics required for the effective use of each information-gathering method.

A customer satisfaction program can lead to improvements in efficiency and effectiveness as well as increase Texans' trust in government by supporting and promoting the accomplishment of an agency's mission and goals and aligning team and individual performance elements with those goals. Tools such as surveys and focus groups can help an agency better understand its customers' needs, provide specific and actionable data to guide service improvement, and introduce fresh ideas into government processes.

Implementing a customer satisfaction program can improve:

- Efficiency:
    - Resource management – In a time of budget cuts and tax limitations, an agency can identify its most crucial programs and redirect its resources.
    - Resolving complaints – Customer complaints highlight problems and help agencies quickly address the cause.
- Effectiveness:
    - Reliable data – Clear plans lead to a clear vision for how information is to be used.
- Public trust:
    - Commitment to customer service – A customer-centered approach tells people what they can expect from government and how the agency measures success. Moreover, incorporating customer satisfaction into published performance measures shows a commitment to meeting customers' needs.

In summary, it is clear that TxDOT has taken great strides in implementing its PM system in only a few short years. Further, according to a recent report by the Pew Center on the States and the Rockefeller Foundation (2011), it appears that the current efforts have already placed TxDOT in the top 13 states in the United States in terms of PM maturity. However, the PM system at TxDOT is still in its infancy and under development. In addition, even a good PM system can typically still be refined and further improved over time. The next section describes a high-level assessment of TxDOT's current PM system against the frameworks identified earlier and resulting recommendations for future development, particularly in one key area: customer satisfaction management.

How Can TxDOT's Performance Measurement Capabilities Be Improved?

With some modification, the holistic Balanced Score Card framework can fit the context of TxDOT operations. The three categories of measures TxDOT uses can match the four categories of the BSC framework:

- internal – internal business process, and learning and growth;
- external – customer; and
- legislative – financial.

In addition, these can be mapped to the three NCHRP framework categories as follows.

- engineering – internal – internal business process, and learning and growth;
- customer – external – customer; and
- fiscal – legislative – financial.

Thus, it appears that TxDOT's current approach to PM encompasses each of the categories. As previously mentioned, TxDOT currently reports on a number of scientific and engineered measures, as well as other internal efficiency measures and legislated fiscal measures. These measures could, at least in theory, span all three categories in both BSC and NCHRP frameworks. However, analysis of the types of measures typically used within each element of the BSC and NCHRP frameworks, as well as the practices of other DOTs, is needed to identify opportunities for improvement in TxDOT's current PM system.

Table 1 maps TxDOT's current performance metrics, along with those that are legislatively mandated, to the three categories of the BSC and NCHRP frameworks. Successful PM programs have measures covering each of the three categories. The table illustrates how the measures relate to each of the categories as well as the goals of the strategic plan.

In particular, in keeping with PM practice, each metric is mapped to the single dimension to which it appears to be most strongly related, although arguments could be made that many of these metrics span multiple dimensions. A more detailed assessment of the PM system is a recommended step for future work (as will be discussed more later in this research brief) and can also be used to further validate the three categories.

It is possible, for instance, that TxDOT might want to develop a fourth category for learning and growth, rather than including these types of measures in the internal category. In addition, although the legislative category is a logical division because it represents the metrics that must be reported to external stakeholders, the underlying nature of the legislative metrics do not always differ significantly from the other categories. For example, TxDOT On-Budget is an internal measure but is similar in nature to the budgetary measure reported to LBB (Construction Projects Completed On Budget and Design Projects Delivered On Budget). Thus, TxDOT may potentially want to develop a slightly different set of performance dimensions than the current three.

Table 1. Mapping TxDOT PM to other PM Frameworks.

		Existing TxDOT Performance Measure	Performance Measure Category			Does the Metric Directly Measure Meeting the Goal?
			Agency Activity (Engineering/ Internal)	Fiscal/ Legislative	Customer Satisfaction	
GOAL	REDUCE CONGESTION	Construction Projects Completed On Time		✓		
		Construction Projects Completed On Budget		✓		
		Design Projects Delivered On Time		✓		
		Design Projects Delivered On Budget		✓		
		Percent of Projects Awarded On Schedule (actual to estimated awards)		✓		
		Right-of-Way Budget ($ expenses/$ appropriated)	✓			
		Right-of-Way Acquisition (% of parcels by negotiation)	✓			

		Existing TxDOT Performance Measure	Performance Measure Category: Agency Activity (Engineering/ Internal)	Performance Measure Category: Fiscal/ Legislative	Performance Measure Category: Customer Satisfaction	Does the Metric Directly Measure Meeting the Goal?
GOAL	ENHANCE SAFETY	Fatality Rate (# of fatalities/100 million vehicle-miles traveled)		✓		✓
GOAL	ENHANCE SAFETY	Roadways with Improved Shoulders (% of two-lane roads with shoulders)		✓		✓
GOAL	ENHANCE SAFETY	Railroad Crossing Signalization (% of railroad crossings with signalization)		✓		✓
GOAL	ENHANCE SAFETY	Traffic Assessment Condition Score		✓		✓
GOAL	IMPROVE AIR QUALITY	Greenhouse Gas Emissions (TxDOT fleet gas emissions)	✓			
GOAL	EXPAND ECONOMIC OPPORTUNITY	TxDOT On Budget (actual expenditures/total appropriations)	✓			
GOAL	EXPAND ECONOMIC OPPORTUNITY	State Highway Fund Revenue Forecast (projected revenues to actual revenues)	✓			
GOAL	EXPAND ECONOMIC OPPORTUNITY	HUB Activity (% of all contract funds awarded to historically underutilized businesses [HUBs])	✓			✓
GOAL	EXPAND ECONOMIC OPPORTUNITY	Project to Funding Ratio (dollar volume of highway projects delayed in the fiscal year)		✓		
GOAL	EXPAND ECONOMIC OPPORTUNITY	Small Urban and Rural Public Transit Trips (% change in non-metro transit trips)		✓		✓
GOAL	EXPAND ECONOMIC OPPORTUNITY	Yearly Letting Caps to Actual Letting Caps ($ volume of actual letting to annual letting cap)	✓			

		Existing TxDOT Performance Measure	Performance Measure Category: Agency Activity (Engineering/ Internal)	Performance Measure Category: Fiscal/ Legislative	Performance Measure Category: Customer Satisfaction	Does the Metric Directly Support the Goal?
GOAL	PRESERVE TRANSPORTATION ASSETS	Pavement Condition (% of pavement in good or better condition)	✓			✓
GOAL	PRESERVE TRANSPORTATION ASSETS	Bridge Condition (% of bridges in good or better condition)		✓		✓
GOAL	PRESERVE TRANSPORTATION ASSETS	Roadway Surface Treatments (# of actual lane-miles surfaced compared to planned)	✓			
GOAL	PRESERVE TRANSPORTATION ASSETS	Texas Maintenance Assessment Program (overall maintenance condition score [pavements and traffic operations roadside conditions] for the state highway system)		✓		✓
GOAL	EXTERNAL PERFORMANCE EINDICATORS	Vehicle-Miles Traveled (roadway usage)	✓			
GOAL	EXTERNAL PERFORMANCE EINDICATORS	Urban Congestion Index (assessment of extra travel time in the eight largest urban areas)		✓		
GOAL	EXTERNAL PERFORMANCE EINDICATORS	Statewide Congestion Index (assessment of extra travel time in the 17 small urban areas)		✓		
GOAL	EXTERNAL PERFORMANCE EINDICATORS	CTTS Forecasting Accuracy (actual vs. forecast revenue for the Central Texas Turnpike System [CTTS])	✓			
GOAL	OTHER	Percent of Motor Vehicle Consumer Complaints Resolved		✓	✓	
GOAL	OTHER	Number of Cars Stolen per 100,000		✓	✓	

Sources: Texas Department of Transportation 2010 Performance Report, ftp://ftp.dot.state.tx.us/pub/txdot-info/sppm/txdot_results.pdf; Legislative Appropriations Request, http://www.lbb.state.tx.us/External_Links/LAR/Transportation_2010-11.pdf.

The far right column of Table 1 indicates the link between the metric as a measurement to support achievement of the goal. As noted earlier, organizations may have a propensity to measure what is easy to measure. In many instances data are collected and reported simply because they are available without making the connection to how the outcome supports the strategic goal. Developing a holistic system requires the linking of the strategic planning process with the metrics, targets, and evaluation. Figure 3 demonstrates the integrated nature of the system. This integration enables organizations to operate effectively and efficiently, while at the same time being transparent and accountable.

Figure 3. Relationship of performance management elements adapted from NCHRP (2011).

One key aspect that is missing from the external performance measures is a direct assessment of the public's perception of how

Table 1 clearly shows that TxDOT has established a number of performance metrics documenting internal performance. Moreover, most of these are also legislative or fiscal measurements. In addition, some of the measures could, at least in theory, be related to the customer dimension, e.g., safety measures. However, one key aspect that is missing from the external or customer performance measures is a direct assessment of the public's perception of how TxDOT is doing. In other words, TxDOT needs to know if the public's perception of Texas' transportation system matches the performance of the technical measures of the functional areas TxDOT is responsible for providing and maintaining. This direct assessment of customer satisfaction is essential to TxDOT, and the best way to find out whether TxDOT's customers – the citizens of Texas – are satisfied is to ask them. As mentioned, the development of a customer satisfaction management program is currently underway at TxDOT, although only preliminary efforts have been implemented so far. We recommend that these efforts be continued and expanded. The remainder of this brief therefore focuses primarily on customer satisfaction as a performance measure.

CUSTOMER SATISFACTION MANAGEMENT

Managing customer satisfaction is a critical challenge for all types of organizations. More than ever, customers today have the power to make or break organizations because they have a wider variety of choices than ever before, greater means of publicizing positive or negative experiences (such as Internet forums, Amazon.com or other online review pages, Facebook, Twitter, or text messaging), and higher expectations for service and product quality. Public-sector organizations are not immune; dissatisfied customers can lobby lawmakers for reduction in funding, management changes, organizational restructuring, or even privatization.

To effectively *manage* customer satisfaction, organizations must first be able to *measure* customer satisfaction. Customer satisfaction measures can be divided into types based on:

- type of data (qualitative or quantitative) and
- data collection method (interviews, focus groups, self-administered survey questionnaires, suggestion system drop boxes, or indirect [proxy] methods).

What Are the Types of Customer Satisfaction Data?

Customer satisfaction data can be qualitative or quantitative.

Qualitative

Qualitative customer satisfaction measures primarily consist of customer comments regarding a given aspect of organizational performance, such as service problems, product strengths, or suggestions for new features. These data contain no numerical

information initially but can be coded to identify common themes and theme frequency. For example, the qualitative customer satisfaction measure *service complaints* could be analyzed over time to track the total number of complaints per month (perhaps as a percentage of total customers) and the top themes in service complaints.
Qualitative customer satisfaction measures may often provide detailed information on the exact nature of customer desires or concerns and allow organizations to discover problems, customer expectations, or process/product improvement opportunities. However, extracting reliable information about importance or performance versus expectations from qualitative performance data is often difficult. For instance, the top-ranked problem experienced by customers in terms of frequency may turn out to be only a minor annoyance to customers, unlikely to affect customer decisions to continue using the product or service or to trust the organization to fulfill their future needs. Meanwhile, a problem ranked somewhat lower in terms of frequency might have a severe impact on customer satisfaction and intention to continue their relationship with the organization.

In addition, compared with quantitative data, qualitative data are often more expensive to collect since they frequently rely on labor-intensive methods such as interviews and focus groups, and are almost always more expensive to analyze. Even with computer support, the coding process is long and labor intensive and requires multiple trained coders (Miles and Huberman, 1994). Further, expert judgment is required to determine when customer responses are similar enough to be combined into the same code, introducing a source of potential error and reduced measurement reliability.

Quantitative

Quantitative performance measures include:

- customer rankings of different alternatives for a given performance criterion, such as importance of different product attributes in purchasing decisions;
- customer ratings for a given performance criterion, such as perceived organizational performance on different service quality dimensions;

- customer behaviors, such as return visits or dollars spent per customer per month; and
- other numerical measures not directly supplied by customers, often called proxy measures, such as facility or equipment age for a city bus fleet; these measures often directly relate to another BSC dimension (for instance, internal processes) but are used as a "stand-in" for customer satisfaction measurement purposes because they are hypothesized to be key drivers of customer satisfaction

How Are Data Rated?

Ratings often use Likert-type scales, which ask the given customer to select the single response category that best describes his or her opinion about the performance criterion being rated. Typically three to 10 response categories are identified per scale and are arranged to define a response continuum that is balanced in terms of the number of positive and negative response categories. Response categories are assigned to continuous-interval, numerical values (with a "1" assigned to either the most negative response category or the most positive response category). Sometimes a "neutral" or "not applicable" category may be used. A "neutral" option receives the middle value of the numerical scale, while a "not applicable" option is placed on one end of the scale and assigned a "0" value. In addition, while often there is a response category assigned for every numerical value, in some scales response categories are only assigned to certain numerical values – for instance, every other value or the scale extremes. Examples of Likert-type scales that may be used for customer satisfaction measurement methods include:

- *satisfaction*: completely dissatisfied (1), dissatisfied (2), slightly dissatisfied (3), slightly satisfied (4), satisfied (5), or completely satisfied (6);
- *agreement*: strongly disagree (1), disagree (2), tend to disagree (3), tend to agree (4), agree (5), or strongly agree (6);
- *quality*: poor (1), fair (2), good (3), very good (4), or excellent (5);

- *importance*: not important at all (1) . . . extremely important (10);
- *extent*: not at all (1) . . . to a great extent (10);
- *frequency*: never (1), rarely (2), sometimes (3), often (4), or always (5); and
- *likelihood*: very unlikely (1), unlikely (2), likely (3), or very likely (4).

Customers may be asked to provide ratings of the organization only, ratings for the organization's competitors, or ratings for the organization compared to its competitors. Comparisons to competitors, using either the ratings based on direct comparison or the ratings for the organization and its competitors, form the basis of the popular House of Quality (also called Quality Function Deployment [QFD]) method used to improve product and service quality (Gustafsson et al., 2000). Further, customers may be asked to rate the organization directly or to rate the organization compared with their expectations. As will be discussed more in the last major section of this report, although these two types of ratings are often assumed to provide highly similar information, it is not clear that they always do.

To improve measurement reliability, often numerical ratings are averaged over a set of related performance criteria (questions or attributes), and this average is used as the performance measure reported in organizational scorecards, e.g., *overall customer satisfaction*. Standardized rated measures of customer satisfaction can define specific performance criteria assumed to be applicable across many types of organizations. For instance, the SERVQUAL survey questionnaire instrument (Parasuraman et al., 1988) developed a standard set of questions intended to be used to measure perceived service quality in organizations of all types. The SERVQUAL framework identified five dimensions of overall service quality, each of which is associated with multiple standard questions:

- tangibles – the physical condition of facilities, equipment, and employees providing the service;

- reliability – the dependability and accuracy of the service;
- responsiveness – the promptness of the service and willingness of employees to help customers;
- assurance – the extent to which employees are knowledgeable, courteous, and able to inspire trust and confidence; and
- empathy – the degree to which the organization provides caring, individualized attention to the customer.

How Are Data Collected?

The data collection method generally does not directly depend on the type of measure (qualitative versus quantitative), with a few exceptions – in particular the suggestion system “drop boxes.”

Data collection methods include:

- *interviews,*
- *focus groups,*
- *questionnaires,*
- *drop boxes, and*
- *proxy measures.*

In an **interview**, a single customer responds to a series of questions asked by an interviewer or group of interviewers. Interviews may be conducted in person (face to face) or over the telephone, including computerized methods such as video-chat and Skype. Questions can be open ended or close ended, where the interviewee is asked to select one or more pre-specified response categories. Meanwhile, the types of data collected can be qualitative or quantitative (rankings, ratings, or self-reported behaviors). Interviews can provide high-quality data because interviewers can ensure that participants understand their objectives, instructions, and questions; can clarify participant answers through probing; and, in face-to-face methods, can provide visual aids to assist participants in understanding questions, instructions, and response options (Borque and Fielder, 2003b; Oishi, 2003).

Interviews can be particularly useful for special populations (e.g., those with low literacy or the elderly), exploratory studies (e.g., a study focused on identifying the types of performance criteria to be included in a customer satisfaction survey questionnaire), and data-intensive studies (i.e., times when a great deal of information is required from each individual, and it is undesirable to gather this information in a group setting).

However, interviews are typically extremely costly, compared to other methods, because of interviewer training and on-the-job costs, as well as the fact that some interviewees expect to be compensated for participation. Further, customers may see interview methods as more intrusive or risky since feelings of anonymity are decreased, resulting in more biased responses to “sensitive questions,” i.e., increased social desirability bias effects. Another limitation is that it is more difficult to preserve a common stimulus across customers, even if a structured interview script is carefully followed, due to subtle interviewer effects (such as facial expressions or tone of voice).

A **focus group** occurs when a (typically small) number of customers are selected to respond together to provide opinions on the criteria of interest. Focus groups are generally conducted face to face, although virtual focus groups are also possible. In general, the recommended group size is six to 10 participants, although smaller and larger groups can also be used (Morgan, 1998). Typically, focus groups collect qualitative data, although quantitative data can also be collected. Further, although data can be collected at the individual level, data are generally aggregated to the group level because the rationale behind focus groups is that the interactions between different members of the group lead to the discovery of consensus opinions. Focus groups have similar strengths and weaknesses to interviews, although the central feature of interaction between different group members leads to some additional strengths and weaknesses. For instance, the intent behind focus groups is that the interaction between group members will help group members sharpen and refine their opinions – that group members can build on one another’s ideas – such that the consensus opinions derived from a focus group are of higher quality than would be derived from separately polling participants and then combining the data. (This is the same rationale behind Delphi studies in organizational research.) However, focus groups can become dominated by more assertive members, and the “group think” phenomenon may also influence results; i.e., some individuals may be unwilling to voice divergent opinions due to social pressures.

A **self-administered questionnaire** is typically distributed to customers in person, via mail, or via email. In a truly self-administered questionnaire, the customer has no interaction with the organization beyond an invitation cover letter, script (if the customer is recruited in person), or email. The customer relies solely on the instructions given in the questionnaire to complete it and then returns the questionnaire to the organization via mail, via email/electronic submission, at a drop box, or in person. Slight variations on the self-administration method include methods where the individual who distributes the questionnaire gives real-time instructions to the customer (typically only for in-person administrations) or answers certain types of questions the customer has about questionnaire instructions (Borque and Fielder, 2003a). (Individuals distributing the questionnaire generally should not answer queries about the meaning of questions or words in the questionnaire itself.) Self-administered questionnaires could also be completed by a group of customers collectively, rather than a single customer individually. Self-administered questionnaires almost always have lower cost and less susceptibility to social desirability bias than focus groups and interview methods, are significantly quicker for most customers to complete, and also facilitate preserving a common stimulus across customers. However a greater burden is on the usability of the questionnaire design (hence the need for careful pilot testing), and response rates may be lower than with interviews and focus groups. Further, the organization has less control over the timing and environment of questionnaire completion than in interviews and focus groups, which can be both a strength (convenience for the customer) and weakness (the influence of potential external factors and the possibility of forgetting to complete the questionnaire). For instance, even if the intent is that the questionnaire be completed individually, customers could theoretically consult other people in answering the questionnaire.

A **suggestion system “drop box”** is a physical or virtual (email address or an online discussion board) receptacle that allows customers to submit comments, complaints, or suggestions in open-ended (free-response) format. Unlike other data collection methods, this method results in qualitative data only. This method can be a useful tool for uncovering new information about customer expectations, needs, and problems, and also allows the customer to respond according to his or her own timetable, rather than the organization's. However, similar data might be obtained by including an open-ended "comments" field in interviews, focus groups, or self-administered survey questionnaires. Further, unlike the customers who may participate in other data collection methods, customers who submit comments using a drop box are solely self-selected. Thus, organizations cannot employ sampling procedures to try to obtain a representative sample of customers as they can with other methods, and organizations might have little to no demographic information about the customers who respond. Further, a customer might submit multiple identical comments without being detected. Thus, this method has relatively low reliability for measurement purposes.

Finally, for **proxy measures and some behavior measures**, data can be collected using a variety of methods, including observation, organizational accounting, or other information systems, depending on the exact nature of the measure. The key distinguishing feature is that these data are not collected directly from customers. Thus, the organization cannot directly infer customer opinions from the data. However, hypotheses about the linkages between these measures and customer perceptions can be developed, and these measures can be used along with or instead of direct customer perception measures. Proxy measures are most convincing if empirical testing by the organization or other organizations, or academic literature has shown the hypothesized linkages to be accurate. Thus, it is important that the organization explicitly state the hypothesized linkages, carefully evaluate them, and test or validate them as soon as possible. If these measures are only used as placeholders or supplementary measures, direct customer perception measures should be developed as soon as possible.

In summary, organizations should use some of the more intensive but costly methods (interviews and focus groups) to collect qualitative data and some quantitative data when initially designing their PM systems and at periodic intervals to refresh their PM systems. For regularly monitoring performance, organizations should use lower-cost methods, self-administered survey questionnaires, and methods to collect proxy or behavior data to collect primarily quantitative data because these methods are more reliable (consistent over time) and more cost-efficient. Qualitative data can be used to identify new problems and opportunities, which may be used to refresh the PM systems or the data collection method. Organizations can also use auxiliary methods, such as drop box suggestion systems, as a supplementary means to discover emergent problems and opportunities.

What Other Elements Need to Be Considered?

An organization must also consider the following in designing its customer satisfaction measurement system:

- data collection frequency,
- customer segmentation, and
- sampling issues.

First, in terms of **data collection frequency**, for ongoing measurement purposes, such as self-administered customer satisfaction questionnaires, data are most typically collected quarterly, semiannually, or annually. Measurements designed to drive system change, such as focus groups intended to identify new customer requirements, may be event driven (due to an organizational problem or opportunity) or time driven (such as annually, every two years, or every three to five years). Drop boxes often collect data continuously, at the will of the customer, until they are closed, although the data collected may only be reviewed at fixed intervals in some cases (such as daily, weekly, or monthly).

Segments can be defined based on demographics or behavior.

Second, in designing its customer satisfaction management program, the organization must consider whether its customers can be divided into meaningful subcultures or clusters – called **customer segments** – that have unique needs, expectations, or problems compared with other customer groups. Segments can be defined based on demographics (such as age or income) or behavior (such as commuters versus non-commuters). Identifying segments can be a difficult process and can be done prior to data collection based on logic or previous literature, or allowed to emerge from the data; i.e., response clusters may be observed based on initial interviews, focus groups, or self-administered questionnaire results. Once segments are defined, the organization can use them for reporting and analysis purposes to answer the question: how well are we serving the needs of customers in each segment? If appropriate, the organization can even design different customer satisfaction measures or data collection methods for different segments. For instance, a customer satisfaction questionnaire may include several questions regarding perceived congestion and travel time versus expectations for a commuter segment, but may not include these questions for the non-commuter segment. Or, an organization might use interviews for a customer segment containing elderly people and self-administered questionnaires for younger segments. Importance values can also be assigned to different segments, if appropriate, based on total size, revenue generated, purchasing power, or other forms of influence.

Finally, in terms of **sampling,** key decisions the organization must make relate to sample selection and sample size. Sample selection refers to the method used to identify individual customers to participate in the measurement efforts. For measurement results to be statistically generalizable to the larger population, a random sampling method must be used. Several different types of random sampling exist; e.g., see Scheaffer et al. (1996). In addition, some methods are more useful than others for certain types of populations; for instance, those with customer segments might benefit from a stratified or cluster sampling procedure. However, some data collection methods, such as drop boxes and potentially some proxy or behavior measures, do not allow random sampling. Further, random sampling may be possible but substantially more difficult than non-random sampling for some other data collection methods, such as focus groups. Useful information can still be drawn from non-random samples; however, the organization must be more careful in generalizing conclusions from these samples due to potential bias by the organization or the customers themselves during the selection process. The second sampling decision, determining the target sample size, is influenced by the selection method used. In particular, for the random sampling methods, an appropriate sample size can be calculated based on population size, expected data characteristics (such as expected degree of variability in perceptions across customers), and desired level of measurement accuracy. Such calculations could also be made for non-random methods, although, again, care must be used in generalizing to the larger population from such data. In addition, there is a clear tradeoff between sample size and cost, although cost per individual customer also depends on the sample selection and data collection methods used.

What Are the Benefits of Customer Satisfaction Management?

As discussed in a previous section, the experience of other DOTs suggests that implementing an appropriately designed customer satisfaction program in DOTs specifically can improve:

- efficiency,
- effectiveness, and
- public trust.

The experience of other DOTs is also aligned with results from the PM literature as a whole. A comprehensive customer satisfaction program can lead to substantial improvements in overall organization performance and credibility. To improve performance, however, managers must apply what they learn from customer satisfaction measurement activities to the decisions they make about a particular program. Furthermore, it is critical to communicate this information throughout the organization to help front-line employees make smart decisions when dealing with customers.

How Should TxDOT Develop Its Customer Satisfaction Program?

As previously mentioned, TxDOT is currently in the process of developing its customer satisfaction management program. To date, the department currently solicits customer input on various programs such as the *Don't Mess with Texas* anti-litter campaign and various safety campaigns. Some divisions, such as the Motor Carrier Division, also routinely gather data on satisfaction with their permit-issuing services. However, many of these efforts occur sporadically and independently of one another. This prevents meaningful data analysis and trend analysis, and misses opportunities for collaboration. Although other, system-level efforts are currently under way, and the department has also developed a guidebook, *Tell TxDOT*, to guide its effort to implement its overall customer satisfaction program, significant work remains to realize this vision.

IMPLEMENTATION ISSUES WITH PERFORMANCE MANAGEMENT SYSTEM CHANGES

As previously noted, a large number, if not the majority, of PM implementations or significant system changes fail. While design problems such as the selection of the wrong measures can certainly contribute to system failure, the literature shows that the majority of failures are linked to problems in the deployment (rollout and ongoing use) of the systems (Bourne et al., 2002; Braam and Nijssen, 2004; Franco-Santos and Bourne, 2005; Meekings, 2005; Meekings et al., 2009; Chearksul, 2010).

What Plans Are Necessary for Implementation?

Previous research suggests that in order to achieve successful implementation, TxDOT must develop effective plans in each of the following areas:

- change management,
- technology integration,
- performance review, and
- strategy maps.

Change Management. In change management, TxDOT must appropriately determine who to involve at what stages of deployment. As previously mentioned, first rolling out the changes with a small group of key stakeholders in one area of the organization is often most effective. While open communication channels can be desired to gather input beyond the employees in the rollout group, attempting to involve too many stakeholders at once or to gather detailed input from everyone in the organization can lead to the failure of the initiative.

Research further suggests that PM system change can be successfully implemented using either a top-down rollout, bottom-up deployment, or some combination thereof (Andersen and Faguerhaug, 2002; Letens et al., 2010). For TxDOT specifically, this means considering the organization’s current culture and capabilities to determine exactly how to roll out the proposed changes and who should be involved when. For example, should change begin in one district (an incremental bottom-up approach), the central office (a top-down approach), or several districts simultaneously (a broader scale bottom-up approach)?

However, whether a top-down, bottom-up, or combination approach is used, research further suggests that the support of management at the highest levels of the organization is critical to implementation success. Further, support must run deeper than verbal support of the changes and must also include the visible behavior of management. Organizational resource allocation and other key decisions made by senior managers must also be consistently aligned with the intended changes. Support of lower-level managers and other stakeholders with a high degree of influence is also crucial but can often be achieved with the strong and persistent support of senior management. Although the exception rather than the rule, in rare cases reassignment may be needed where an individual cannot be convinced of the value of the change.

Technology Integration. Electronic data repository and electronic data-gathering mechanisms are often required to support PM changes. TxDOT must consider how the changes will interface with its existing information technology (IT) and current personnel IT capabilities (Leinonen, 2001; Franco-Santos and Bourne, 2005; Franco-Santos et al., 2007). In designing changes to its PM system, TxDOT should simultaneously audit its existing IT systems. Key questions include the following: What supporting IT changes will be required? When will IT changes occur and at what cost? Are these changes feasible given the needed implementation timeframe and TxDOT's budget? If not, what changes to the proposed PM system design will need to be made?

Performance Review. TxDOT must clearly define exactly how data will be used as part of ongoing performance review (Marr, 2006; Meekings, 1995, 2005; Neely et al., 2006; Meekings et al., 2009; Chearskul, 2010; Farris et al., 2011), including:

- At what organizational level will each measure be reviewed and at what frequency?

- Who will be the metric owners? Will the metric owners collect the supporting data, or will the IT system or other individuals handle this step?
- What methods will the owner use to communicate performance results during performance review meetings and to other stakeholders, e.g., graphical review templates?
- What statistical and other tools should be used for metric analysis, and to what extent should analysis be done before versus during meetings?
- How should decisions be made regarding actions to improve organizational performance on metrics? What problem-solving tools or causal models, such as strategy maps, should support these decisions, who should be involved, and how should consensus be reached?
- How should decisions and the effects of improvement actions be communicated to the rest of the organization?
- How should the effects of improvement actions be tracked over time, and when should decisions be made to modify improvement actions?

TxDOT will have to develop, deploy, and continuously refine a comprehensive performance review plan addressing all these elements as it implements changes to its PM system. Although it may sometimes be necessary to collect certain data purely for the benefit of external stakeholders, for the most part, PM data that are not used effectively to support some form of organizational decision making are ultimately worthless or, worse, detrimental. Although not all elements may be addressed initially, the sooner TxDOT is able to achieve an effective performance review process of new PM data, the sooner it will see the benefits of collecting these new data.

Strategy Maps. The literature suggests that it is absolutely critical that TxDOT define and test a causal model of organizational performance, i.e., a model, often called a strategy map, that describes the hypothesized relationships between different measures in the PM scorecard. Organizations that both develop and test strategy maps, using the performance data collected over time, have the most successful PM implementations (Ittner and Larcker, 2003; Chenhall, 2005). A first step in developing strategy maps is identifying what performance measures relate to the organization's current strategies and goals.

TxDOT may have taken the first step in this process with the development of the 2011-2015 Strategic Plan. The plan outlines broad goals and the strategies for achieving them. Figure 4 illustrates the TxDOT example.

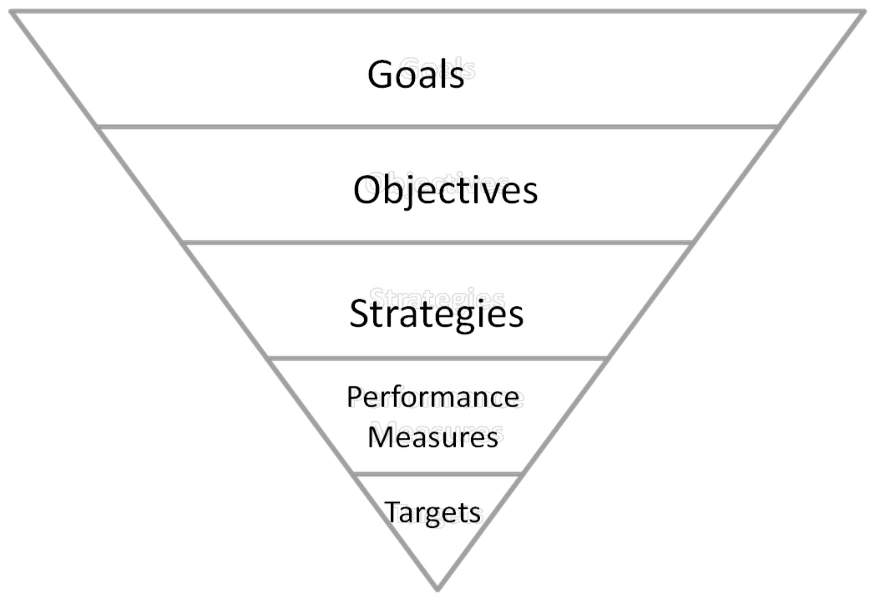

Figure 4. TxDOT strategic planning process.

The next step is identifying how the different performance measures an organization uses are related (e.g., see Figure 1). This allows the organization to identify which measures must be influenced first to ultimately change others, as well as potential negative side effects (unintended consequences) of improving certain measures. For instance, TxDOT might hypothesize that current investments in improving pavement condition and reducing congestion will improve safety once construction is complete, which will ultimately improve legislature satisfaction with TxDOT after a certain time lag. This causal chain can be graphically stated within a strategy map (Figure 5), thus improving stakeholders' understanding of exactly how performance improvements can be achieved and what measures to track to determine whether progress on strategy implementation is being made. Specific action plans and timeframes (including potential time delays for seeing impacts) could also be added to the strategy map.

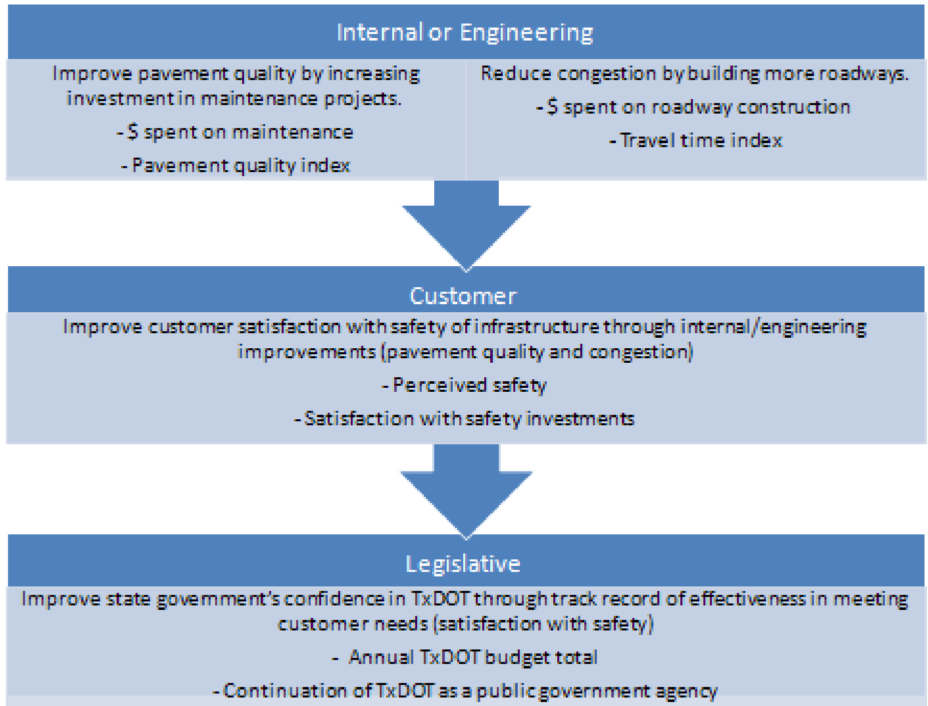

Figure 5. Hypothetical strategy map for TxDOT.

Explicitly stating hypotheses in the form of a strategy map also makes it easier for the organization to test the validity of these hypotheses and to correct faulty hypotheses (assumptions) as needed, to uncover the true determinants of organizational success. This will help the organization continuously improve its performance to operate more efficiently and effectively over time.

What Are Some Specific Implementation Concerns?

Although following the example of previous successful DOT implementations and addressing the points raised above will improve the effectiveness of PM system implementation at TxDOT, staff at TxDOT and other DOTs have expressed some other legitimate implementation concerns. These can be addressed with good communication techniques that focus on explaining the information rather than simply presenting the numbers, such as providing information in a format that others can use to evaluate the measures or create different geographic groupings of measures. These concerns include the following:

- Staff members do not consider the measures to be relevant. The remedy is to involve the staff in developing the measures.

- Staff members that are being measured cannot control the measure outcomes. The remedy is to describe the limitations and applications of the measures, and to avoid using measures not under the control of staff for performance evaluation purposes.

- The measurement requires additional time and data. The remedy is to connect the measurement process with operations and investment decision making.

OTHER RECOMMENDED SYSTEM CHANGES

The majority of the PM system changes described in this brief focus on customer satisfaction measurement since this was identified as one of the key strategic areas most in need of additional development in TxDOT's current PM system. Despite the great amount of improvement that has been achieved in only a few short years, TxDOT's current PM system is still very young, and other, more specific areas may also present opportunities for further improvement, e.g., developing some metrics focused on employee satisfaction or capabilities within the internal performance dimension. Thus, in addition to the recommended developments in customer satisfaction, we also recommend that TxDOT commit to a more detailed assessment and benchmarking study of its current PM system than this high-level strategic research brief can provide. This assessment should include all organizational levels, including all 25 of the TxDOT districts and the central office. This will require a significant commitment of time and other resources from TxDOT personnel, as well as a partnership with a university, research institute, or external consulting agency.

Thus, we recommend that TxDOT seek to expand its current PM capabilities while preserving improvements already realized and recognized by the Pew Center on the States and the Rockefeller Foundation (2011). In addition, we believe TxDOT should preserve its three current core performance measure categories – at least until a more detailed assessment is conducted – because these are aligned with the BSC and NCHRP frameworks. Based on a comparison of the BSC and NCHRP frameworks to TxDOT's existing system, one key avenue for additional development is the implementation of a formal customer satisfaction management program. A more detailed assessment of the entire PM system may reveal other key areas for improvement.

QUESTIONS THAT REMAIN UNANSWERED

Several questions still require further investigation before TxDOT pursues changes to its current PM program. Some questions refer to PM system design, while others refer to implementation. These questions include the following.

Questions Related to Customer Satisfaction Management

- Should TxDOT seek to develop one common customer satisfaction measurement system for all 25 TxDOT districts and the central office, or should the program be customized to the different sub-organizations? If customized, to what extent?
- How should the organization define targets for customer satisfaction measures, particularly perceived measures? In particular, TxDOT should be able to apply statistical process control concepts to customer satisfaction measures to determine when observed variation is due to true changes in the system (trends or paradigm shifts) rather than normal statistical variation. This requires the development of reliable, quantitative measures and the identification of the normal range of variation for these measures.
- What should TxDOT do if customer satisfaction appears to be strongly linked to measures or other factors outside TxDOT's control? How can TxDOT use this PM data to

improve relationships with customers, rather than potentially see a decrease in customer satisfaction and credibility due to perceived inaction? This requires the identification of uncontrollable factors that are likely to influence customer satisfaction and the development of a carefully crafted communication strategy for uncontrollable measures.

- What should TxDOT do if customer satisfaction appears to be strongly linked to "surface" features, such as pavement appearance, that require significant investment of resources but do not support the maintenance of scientific and engineered standards? Without the investment of additional resources in the system, shifting resources to focus on these features can cause resources to be taken away from the maintenance of scientific and engineered standards, leading to the long-term degradation of the transportation infrastructure, which appears to have been the recent experience of the Missouri DOT.

- What degree of correlation exists between measures that focus on customer expectations versus those that focus more directly on customer satisfaction? One key measure related to customer satisfaction – service quality – has been conceptualized as the gap between customer expectations of performance and perceived actual performance (Parasuraman et al., 1988). In theory, therefore, an organization can improve its service quality (and thus likely its customer satisfaction) by changing either system performance perceptions, customer expectations, or both. Further, questions in customer satisfaction questionnaires asking about the extent to which system performance met customer expectations should, in concept, provide similar results to items asking directly about satisfaction with system performance. However, it is clear that this is not always the case (Parasuraman et al., 1988). If research shows the two types of measures are strongly related for TxDOT's case, is one or the other preferred for PM purposes for other reasons?

- What communication and training strategy is needed to prepare TxDOT personnel to appropriately use customer satisfaction measures? To what extent should employees understand how measures are calculated? What training or communication strategies can be used to increase understanding?

- What resources specifically are needed for deploying a customer satisfaction measurement system within TxDOT? Can TxDOT acquire the needed resources? Within what timeframe can this occur? What can be done in the short term with existing resources? How can long-term resource requirements be reduced?

Other Questions

- In trending performance over time, how should TxDOT deal with the fact that roadways and infrastructure elements will invariably age until overhauled or replaced? Should TxDOT adjust targets for measures or the measures themselves, e.g., reporting current performance as a ratio of the expected performance given the age of the infrastructure element rather than the raw performance score? How can TxDOT clearly communicate with internal and external stakeholders regarding these issues, particularly if raw scores are reported?

- How, specifically, should TxDOT management best champion current PM efforts and any needed system changes? It is widely noted in the organizational change literature that senior management support is critical to the success of any organizational transformation effort. In addition, this support must go beyond surface-level buy-in to reflect a deep, visible, and active commitment rooted in behaviors aligned with the philosophies behind the initiative. What actions can the TxDOT management team take now and in the future that will be most effective in demonstrating their commitment to the PM efforts to TxDOT employees, customers, and other stakeholders?

- What other opportunities for PM system improvements exist? Should improvements be made system-wide (across all districts and the central office), or is it appropriate to customize some changes at the district level? What resources and timeframe are required for these changes? What changes can be designed and implemented by in-house TxDOT personnel, and what changes will require assistance from external personnel? A comprehensive PM system assessment, preferably by external parties, will help TxDOT answer these questions.

- How will the currently reported PM integrate with the new customer satisfaction measures? If the technical measures and the public perception measures vary widely, how will this be addressed? Will funding and operating decisions be modified? Will public information programs be used as educational tools?

Careful investigation of these questions and others that arise should prepare TxDOT to develop a comprehensive and robust plan to implement the needed changes to its current PM system, particularly those related to customer satisfaction management. The benefits of such changes could be huge and are expected to far outweigh costs in the long term.

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ABOUT TTI

This research brief was jointly prepared by the Texas Transportation Institute (TTI), a part of The Texas A&M University System and an agency of the State of Texas and Texas Tech University.

TTI's program of practical, applied research helps hundreds of sponsors address a range of transportation challenges. For example, through decades of research in just the highway area – planning, design, construction, maintenance, safety, and operations – virtually every mile of roadway in Texas has been positively impacted by some aspect of the TTI program. Through research, development, and technology transfer, TTI is helping to meet the transportation needs of tomorrow.

Our mission is to solve transportation problems through research, to transfer technology, and to develop diverse human resources to meet the transportation challenges of tomorrow.

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ABOUT TechMRT

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The SRP program is jointly guided by a three-institution consortium comprised of the Center for Transportation Research at The University of Texas, the Texas Transportation Institute at Texas A&M University, and the Institute for Multidisciplinary Research in Transportation at Texas Tech University.

Texas Department of Transportation
Providing safe, effective, and efficient movement of people and goods.

Strategic Research Program – Research Brief

The Future of Texas Freight: Roles, Forces, and Policies

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Strategic Research Program Purpose

The Texas Transportation Commission established the Texas Department of Transportation (TxDOT) Strategic Research Program in 2011 to assist the department with its number-one goal: preparing for the future. This series of research briefs is intended to identify and frame transportation challenges Texas will face over the next 10 to 30 years. In support of that goal, the briefs attempt to spur discussion within and outside of TxDOT to address issues that TxDOT's stakeholders, interest groups, the Texas Legislature, TxDOT Administration, or the Transportation Commission foresee affecting the efficiency and viability of the state's transportation system.

Using current literature, interviews, and other sources, briefs are meant to provide the reader with an overview of the subject and emphasize the strategic elements of a topic that may need further development, either focused research or internal TxDOT actions. The briefs themselves are not intended as a detailed examination of current or planned TxDOT activity.

This research brief takes a look at the roles, forces, and polices affecting freight transportation in Texas and identifies some strategic issues that TxDOT should consider when formulating its goals as a facilitator of the goods movement industry.

The Future of Texas Freight: Roles, Forces, and Policies

INTRODUCTION

The transportation of freight is the life blood of the economy.

The transportation of freight is the life blood of the economy. Goods and materials flow in vast quantities from production sites to manufacturers and from manufacturers to customers in a highly complex, cost-minimizing system that has developed over many decades. This system has achieved high levels of efficiency and responsiveness that in turn have fueled economic growth in both domestic and international markets.

However, for all of the accomplishments of the modern freight transportation industry, very real and significant problems are emerging that threaten to constrain trade and limit future economic development:

- growing roadway congestion on a deteriorating highway infrastructure,
- escalating fuel costs and a completely oil-dependent transportation sector,
- safety concerns resulting from mixing freight and passenger transportation on highways,
- air quality concerns,
- a capital- and capacity-constrained railroad system,
- stagnant dredging activities in our nation's ports and waterways,
- port congestion,
- labor issues, and
- ever-increasing infrastructure maintenance costs.

CURRENT SITUATION

Highway Trust Fund

The current U.S. model for building and maintaining highways initially flourished in the 1950s with the Interstate Highway System expansion and has evolved over subsequent decades. It was thought to be almost a perpetual-motion machine – fuel tax revenues from ever-increasing demand could fund and maintain an ever-expanding network of roadways. The resulting highway infrastructure facilitated a boom in trucking, an industry that enjoyed the ample capacity and wonderful operational flexibility afforded by this publicly provided coast-to-coast roadway network. Trucking soon became the dominant land-based way to move freight. Times were good.

As more highways were constructed and more users were encouraged to take advantage of the available infrastructure, social and economic developments and new business strategies began to adjust to the cheap, ample transportation resources. The ramifications of these development patterns, too numerous to detail here, included trends like suburban sprawl where people lived substantial distances from their places of employment, just-in-time manufacturing where transportation and delivery timing added greatly to the profitability of the enterprise, and, perhaps most notably, the use of highways as "rolling warehouses" that minimized the cost of inventories and added to business productivity.

Since the completion of the Interstate Highway System, prosperity in the United States has been widespread. A substantial part of this prosperity has been directly attributed to our excellent highway system. Population growth, affordable automobiles – sometimes several per family – and the great American love for the road, coupled with the explosion in trucking, have effectively consumed whatever excess capacity we once had. Energy prices (and hence more fuel-efficient cars) and higher costs associated with labor and materials, aging infrastructure, and the sheer magnitude of the highway system that has been built seem to have interrupted the spinning of the highway funding mechanisms once thought to be able to keep pace with growth.

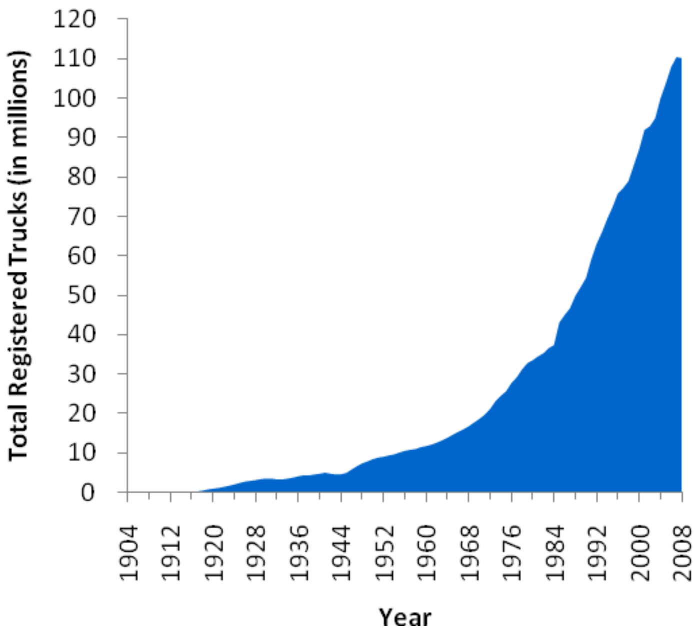
The Intermodal Revolution

The creation of standardized containers has transformed the movement of goods and materials by linking steamship lines with railroads and trucking systems to provide a seamless transportation network that can move cargo from overseas suppliers to retail outlets in sealed containers. Container ships, trucks, and double-stack container movements by rail operate in concert to facilitate the transport of ever-increasing quantities of materials. Container transport in the United States reached more than 32 million twenty-foot-equivalent units (TEUs) in 2008.[1] All modes move bulk commodities efficiently, but the real specialists for transporting large quantities of materials remain the railroads, barges, and ships, where their capacity and energy efficiency make long-distance moves very economical, even from a global perspective.

The more efficient the transportation system, the more rapid and diversified the development of business and industry.

Economic Development and Freight Transportation

Transportation system performance and economic development are intrinsically linked, and the more efficient the transportation system, the more rapid and diversified the development of business and industry. This development is highly correlated with job creation and rising standards of living. While there are many examples of this linkage and the resulting economic prosperity, from ancient seaports to modern industrial development along highways and railroads, the Interstate Highway System in the United States stands as a prime example of the positive economic implications of improved transportation resources.



Source: U.S. Department of Transportation

Figure 1. Registered trucks per year.

As a result of the Interstate Highway System, transportation providers allowed massive (albeit unplanned and unanticipated) growth to take place as a function of essentially free highway resources and capacity (Figure 1). The creation of excess capacity on the highway network, ostensibly for a "national defense transportation system," was unprecedented and provided the always-opportunistic private sector with new opportunities to exploit the low-cost resource provided at the taxpayer's expense. Over the past 50 years, the explosion in the number of trucking companies and the manner in which business adapted to take advantage of the opportunity radically transformed the economy.

[1] http://www.bts.gov/publications/pocket_guide_to_transportation/2011/. Accessed 30 March 2011.

Highways are now used as "rolling warehouses," minimizing the amount and cost of inventories and elevating business productivity.

The emergence of just-in-time (JIT) manufacturing strategies propelled the economy forward and employed the highways as "rolling warehouses" that minimized the amount and cost of inventories and elevated business productivity. Timing shipments to arrive at their point of need just as they were to be consumed or employed in manufacturing greatly reduced the quantity of inventory required to be warehoused in anticipation of orders and shipment. The temporal-spatial planning consideration that made this new view of delivery work was, of course, delivery-time predictability, which in turn depended on the uncongested highway infrastructure that had been provided.

The excess capacity that existed 20 to 30 years ago has been consumed by these new business strategies and by a growing, mobile population. Since 1980, lane miles on the highway have remained virtually unchanged, while vehicle miles traveled on those lanes have nearly doubled. Rail has seen comparable growth in the amount of ton-miles traveled, but due to deregulation and the subsequent abandonment of many branch rail lines, the amount of active track miles has been almost cut in half (Figure 2). As a result of this capacity constraint, the last few years have seen diminishing returns associated with the efficiencies brought to bear on logistics strategies, with transportation now accounting for more than 10 percent of the cost of goods sold. As capacity becomes less available, economic growth and the efficiency of business practices will likely suffer a corresponding decline, and will result in serious ramifications on the commercial sector and the manner in which we do business in this country. However predictable it may be, if the consequences of the decline in transportation capacity remain as equally unstudied and unplanned as was the decades-old gift of free capacity, economic health will suffer more than necessary. Strategic research should focus on the economic implications of fewer

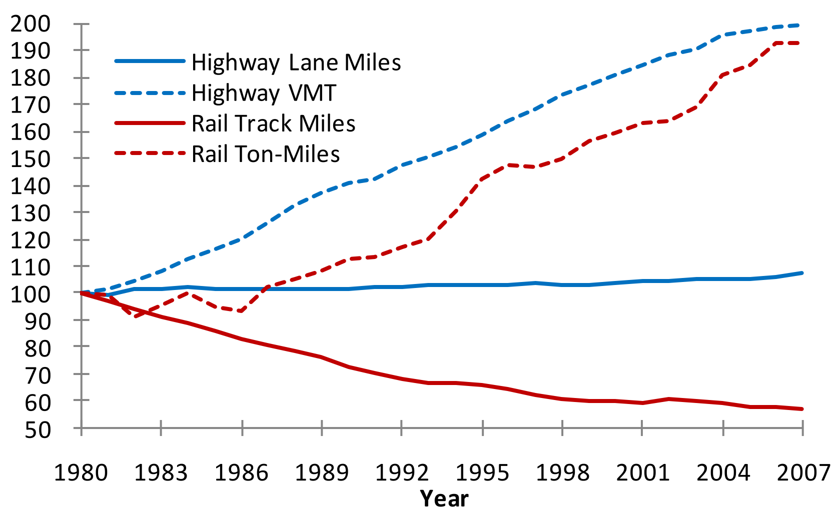


Figure 2. Highway lane miles and vehicles miles traveled (VMT) compared to rail track miles and ton-miles.

transportation resources per capita, and a program should monitor the strategies employed by the private sector to compensate for emerging capacity and operational constraints.

Product Diversification

Intensifying the growth in demand for transportation services is the astounding product diversification that has taken place over the last 10 to 20 years. A remarkable increase in the number of products offered to consumers has occurred over just the last decade, resulting in a significant increase in the complexity of the logistics function for many companies. The American economy is superbly responsive to consumer demand, and given the means, it has shown that it can employ product differentiation to segment markets and create product lines specifically designed to win market share. This process continues in full swing and has resulted in an ever-increasing number and variety of products designed to address a finer slice of consumers in an increasingly more sophisticated society and marketplace. The transportation and logistical implications are immense. When coupled with global suppliers and international customers, the economy's dependence on sound, economic, and predictable transportation is greatly heightened. Collection and distribution systems are increasingly complex – arrayed as hierarchical dispersion systems and carefully placed geographically – and rely on real-time point-of-sale data to drive the delivery of the right product at the right time to the right location.

Globalization

Furthering the increased complexity in goods movement is the headlong drive toward a global economy. International trade and the globalization of the world economy have created a whole new level of volatility in markets and hence in the dynamics and rate of change in transportation needs. There is now a highly dynamic element to business location issues and the transportation needs that result. Today, more than in times past, if one physical location suffers from deteriorating transportation capabilities or flexibility, a company must, for the sake of shareholder value and perhaps survival, evaluate the benefits of relocation or partial relocation to sites that offer superior transportation options. Dell Computer Corporation relocated some of its Austin, Texas-based operations to Tennessee for just these reasons. The new Dell facilities are at the crossroads of three interstates – I-24, I-40, and I-65. Much of the nation's cross-country traffic breezes around and through Nashville every day, and though the roads can be congested at rush hour, they are not as gridlocked as I-35 or MoPac Boulevard in Austin.[2]

Shippers are continually looking for transportation work-arounds to overcome bottlenecks in their network that emerge as a result of the planning windows set by the state.

The volatility in market dynamics and the implications for the transportation systems supporting commercial activity have real consequences for most state departments of transportation. Public-sector transportation planning is not well suited to and may not be able to keep up with the rate of change found in globally driven business decision making. A 20-year, public-sector planning horizon made ample sense when roadway construction was undertaken more in anticipation of demand than is the case today. Railroad planning is usually undertaken within a 5-year capital plan that has allocations made for near-term projects ranging from 1 to 2 years. In contrast, corporate entities make transportation decisions as rapidly as the marketplace requires, and major private-sector providers and shippers are continually looking for transportation work-arounds to overcome bottlenecks in their network that emerge as a result of the longer-term planning windows practiced by the state. In 2002, Wal-Mart found its supply chain integrity adversely impacted by a longshoreman strike at the Ports of Los Angeles and Long Beach. In response, the mega-retailer diversified its warehousing and distribution strategy and opened major distribution centers at Cedar Crossing near the Port of Houston and Savannah, Georgia, effectively spreading the geographic risk associated with critical imports closer to their respective markets.

TxDOT's Mission

The Texas Department of Transportation's (TxDOT's) mission is to provide for the safe and efficient transport of people and goods. This role is critical to maintaining and expanding not just the economic underpinnings of our society, but to maintaining the mobile and flexible lifestyle that we have come to depend on. The interdependence of the basic elements that compose our way of life

[2] Pletz, John. "Dell Starts Fast in Tennessee." *Austin American-Statesman*. January 26, 2005.

is made possible by the efficient transportation of everyone and everything. Think for a moment of a culture where one must employ rudimentary means to transport everything that makes sustenance possible and the complete restriction of activity and degrees of freedom that that restriction entails. Clearly this describes an extreme at the opposite end of the spectrum where we see our society and the opposite point from where we wish to be.

Rather than moving away from this restrictive condition, a host of factors threaten to reverse the trend of the last 200 years – where ever-more efficient and flexible transport has been possible and, in the current public mindset, expected. While the near-term deterioration in our transportation system may be small in relative terms, it nonetheless represents a step backwards, toward unwanted, undesirable transportation restrictions that limit economic activity and society's available options.

PROBLEM DEVELOPMENT

Understanding the Goods Movement Industry

A clear understanding of the characteristics, motives, constraints, and goals of the goods movement industry is fundamental to a strategic and mutually beneficial interaction with freight transportation providers, and hence is fundamental to optimizing the public-sector's facilitating role. Freight transportation is a private-sector undertaking with cost-minimization as a central goal. Few customers in the highly competitive global marketplace fail to energetically plan for the lowest-cost transportation of goods and materials. To do otherwise is simply poor business and can lead to business failure. Success in logistics practices, on the other hand, can lead to success as evidenced by Wal-Mart, which has built one of the world's largest retail operations based largely on its low-cost, sophisticated transportation practices. It is one of a growing number of companies that promote senior logistics executives to chief executive officers.

Freight transportation is a private-sector undertaking with cost-minimization as a central goal.

To be accurate in this very basic formulation of the low-cost emphasis in goods movement, it is necessary to include all of the factors that contribute to the cost-minimizing function and draw distinctions between the private-sector emphasis and that of the public sector. Clearly, things like transit time matter to the private sector in much the same way dollars do, in keeping the total costs down – time is money. Among the factors that are at the top of the list for the trucking industry are the current restrictions on truck size and weight that limit productivity. As energy prices rise, there is corresponding pressure from industry to increase the allowed weight for trucks. Some proposals include adding an axle to offset the potential for greater pavement distress, but these are generally opposed by departments of transportation that cite bridge fatigue as a remaining concern.

Damage to goods in transit represents another category of costs to be minimized, as do worker injuries. And perhaps most critically avoided are major transportation incidents that carry the potential for significant corporate liability. Many small and mid-size transportation firms have been put out of business as a result of the assorted costs (legal judgments, etc.) stemming from highway collisions or other serious transport-related incidents. Between 2003 and 2009 in Texas, there were 390 cases stemming from trucking-related collisions, with an average judgment of $6.7 million and a high verdict of over $23 million.[3] Thus, it is accurate to contend that while the goods movement industry seeks to provide a safe environment for its employees and, as good corporate citizens, seeks to operate safely for everyone's sake, it also keeps a keen eye on risk management and avoiding the potentially devastating economic ramifications of negligent operating practices.

The practice of regulating safety in the freight transportation industry introduces a contentious element into the regulatory relationship that complicates strategic cooperation.

But the goods movement industry generally opposes being required through prescriptive safety regulations to operate in a manner that the public sector has determined is "safe," opting instead for performance-based criteria that leave the private transportation specialist in charge of determining those operating practices that are both safe and cost-effective. Thus, the practice of regulating safety in the freight transportation industry introduces a contentious element into the regulatory relationship that complicates strategic cooperation.

[3] http://www.gpsfleetsolutions.com/GPS-Tracking-and-Driver-Safety.php. Accessed 30 March 2011.

Just as the public sector regulates safety practices, it regulates environmental affairs through the activities of the Environmental Protection Agency (EPA) and EPA's various state counterparts (in Texas the Texas Commission on Environmental Quality [TCEQ]). The regulations governing air quality and mobile emissions dramatically affect the freight transportation industry both operationally and economically. Today, few will argue the point that our oil-based transportation sector is a significant contributor to air pollution. The designation of non-attainment areas and the pressure applied to states and equipment manufacturers to clean up the air are an operational reality for most providers of freight transportation services, and the impact of the costs to mitigate harmful emissions has been felt for many years.

While emissions are appreciably lower, the effective miles-per-gallon figures today closely resemble those of 20 years ago.

As energy prices have risen and become more volatile, the pressure for more efficient engines has resulted in improved technology and gains in miles per gallon of fuel achieved. However, this adept response by private industry, engine manufacturers, and the buyers of new equipment has been routinely offset by more stringent emissions demands placed on manufacturers by EPA. The net result is that, while emissions are appreciably lower, the effective miles-per-gallon figures today closely resemble those of 20 years ago for diesel tractor-trailer rigs, at about 6.0 miles per gallon (MPG) (Figure 3).

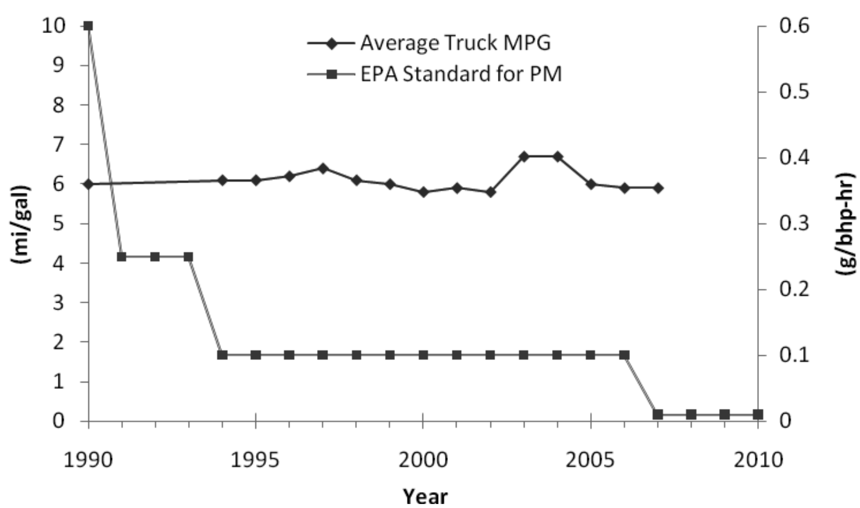


Figure 3. Average truck MPG compared to the EPA standard for particulate matter (PM).

Higher costs will be and are passed along to the customer, whether that customer is a shipper of raw materials or a retail customer in a store.

Undeterred, and with today's $4 per gallon diesel and tightening air quality regulations, the trucking industry remains keenly focused on new propulsion systems such as hybrid-electric engines, fuel cells, and natural-gas-powered trucks. The implications for moving away from diesel as the primary source of energy are serious for the Highway Trust Fund. Continued increases in VMT, accompanied by decreases in gallons of diesel sold, lead to decreases in fuel tax revenues flowing to states for maintenance and expansion of the highway system.

It is important for transportation planners to recognize the fundamental principle of our highly competitive, cost-minimizing goods movement industry: higher costs will be and are passed along to the customer, whether that customer is a shipper of raw materials or a retail customer in a store. In times of rising costs and deteriorating performance indicators, competitive advantage among carriers and providers of logistics services is, therefore, measured not on the absolute terms of service price but rather on the relative measure of what it costs the other guy, the competition, to get goods to market.

"I don't have to outrun the bear – I just have to outrun you."

GENERAL SOLUTIONS

"I Don't Have to Outrun the Bear – I Just Have to Outrun You"

Freight transportation is guided by a principle of relativity, and we contend that regional economic advantage or disadvantage is judged in much the same fashion. We propose that, from the public sector's vantage point, the notion of "relative superiority" in freight transportation systems may be sufficient to attract business and freight activity to a region, and thus the state needs to expand its focus to actively keep abreast of developments in adjacent states and regions. A sound strategic approach may be to work to keep a step ahead of others through a planning function dedicated to anticipating, integrating, and expanding the relative competitive advantage that Texas currently enjoys.

Private-sector freight transportation providers need only be the least inefficient among those competing for freight transportation business. Shippers (and carriers) need only be more efficient than their competition to obtain a competitive advantage (in light of congestion, rising fuel prices, etc.). This hyper-competitive environment gives rise to the inconvenient practice (from the public-sector planning perspective) of carefully protecting information – closely held, proprietary data and confidential routing and rate data for their contracted customer base. These realities make it hard for the public sector to effectively anticipate trends and facilitate freight networks that are responsive to rapidly changing market conditions. The downside of being out of sync with the freight industry is that the higher costs exacerbated by network inefficiency will also be passed on to the customer and blunt overall economic growth.

"A rising tide raises all ships."

"A Rising Tide Raises All Ships (A Drought Parches All Lips)"
From a transportation planning perspective, knowing that freight behaves much like water, flowing along the path of least resistance (in the case of freight, along the path of least cost), should give rise to a perspective that examines freight transportation systems and networks more holistically than is currently the case. It is becoming increasingly important for public-sector planners to view freight transportation as a national, regional, or, at a minimum, multistate enterprise, where local performance is dependent on system-wide considerations. The efficient flow of rail in Texas markets, for example, may be directly impacted by network factors in neighboring states, the mitigation of which can have positive consequences for Texas shippers.

The water analogy can be applied globally or locally. The Panama Canal expansion is expected to alter global freight flows by changing the economics of container shipping, opening more all-water routes from the Pacific Rim to the East Coast and potentially reducing the quantity of goods shipped from California by rail to the Midwest. The consequences for both railroads and roadways, while still undetermined, could be important. If viewed as a zero-sum game, roads and rail all across the country will either lose or gain traffic, and planners at state departments of transportation, without the means to anticipate the changes, will once again be placed in the position of having to respond rather than anticipate change. At a more local level, as congestion worsens in heavily traveled Texas corridors such as I-35, trucks, behaving like water, will seek alternative paths, and some will find their way to lowerdensity roadways such as state highways and farm-to-market roads in order to reduce travel time. The lower engineering standards associated with these roads, which were built to support less traffic, farm equipment, and light trucks, will result in rapid deterioration of the facilities and accelerate the maintenance cycle, thereby intensifying the capacity-versus-maintenance dilemma facing TxDOT today.

"Think globally, act locally."

"Think Globally, Act Locally"

The slogan for the World Health Organization has been co-opted by numerous entities to reflect their own mission; community planning organizations and political action groups are just two that can be cited. The concept being communicated obviously relates to developing and holding a "big picture" view of a situation and then focusing one's efforts on a smaller aspect of the problem or opportunity, thereby making a tangible contribution.

Its pertinence to freight transportation planning from the public perspective is twofold:

1. As has been discussed, freight transportation networks are multistate, regional, or national systems: their operations and dynamics need to be understood from the global perspective. Rail systems, for instance, have an operating hierarchy whereby local circumstances impact regional operations and regional matters similarly affect the entire network, which for the Class I railroads span several states. Similar considerations are true for waterways and highways.
2. Among public-sector planning considerations should be programs designed to facilitate total freight network development and maintenance through a system-wide assessment and appreciation of need. Specific program actions may be local in scope and may be restricted to a single sponsoring state, but coordination between stakeholder states could help maximize the aggregate, mutually beneficial impacts of a coordinated set of local actions.

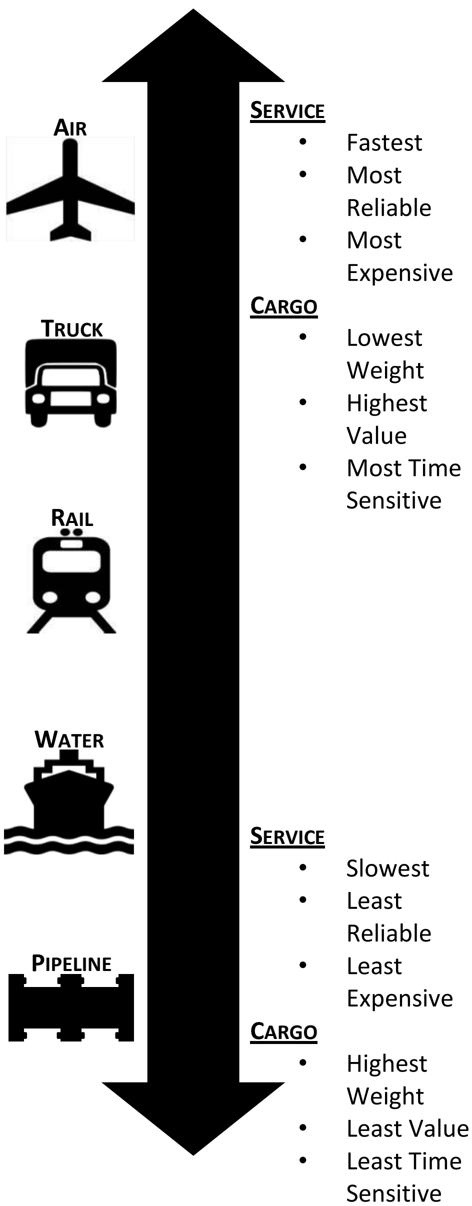


Figure 4. Freight service continuum.

"How does the public sector help optimize the multimodal system of networks that compose the goods movement industry?"

Multimodal Balance

Taking this idea a step further, the public sector needs to develop a planning function that integrates the interrelationships between modes (Figure 4). Specifically, understanding the different strengths and weaknesses and unique characteristics of each mode is essential to developing a strategic plan of action. Building on the knowledge that trucking is the most flexible mode of transport and the one mode that links most others together, the difficult question arises: "How does the public sector help optimize the complex, partially public, mostly private, multimodal system of networks that compose the goods movement industry?" Railroads and waterways – as static and partially disconnected systems – are frequently unlinked to their ultimate customer, and thus efficient trucking connections are critical. While many important exceptions to this consideration exist (e.g., DOW Chemical on the Gulf Intracoastal Waterway, which ships product directly by both rail and barge), numerous examples to the contrary suggest that trucking remains the key element in many supply chains.

Viewed in the near term, with an eye to the mechanisms that are currently available, the question posed above may not be that difficult. To immediately support and enhance the interdependencies between modes, several actions by the state can be readily recommended:

- Connections between modes need to be identified and strengthened – this may often refer to the "last-mile" connectors that are too often the orphaned project, not rising to a level of importance sufficient to attract either state or local investment. Ports, generally speaking, present an unusually difficult linkage challenge. They are almost always "city locked," and connections to customers must be made through urban and sometimes suburban developments, adversely impacting the surrounding community.
- Encroachment onto freight-related rights-of-way needs to be identified and controlled – the urbanization of America creates demand for real estate that often encroaches on or at least approaches freight facilities and property. Urban development up to and around freight rail systems may

serve to constrain the ability of railroads to expand critical links or passing sidings, thereby restricting the enhancement of freight systems and limiting their ability to adapt to increased demand for services. Similar encroachments, largely of a recreational nature, on inland waterway systems limit the ability of industry to expand operations or fully use waterways as a strategic transportation option.

- System bottlenecks need to be identified and remediated, possibly through appropriately configured public-private partnerships (PPPs).
- Access to distribution centers and intermodal facilities can be made more efficient by working with private-sector planners – perhaps there should be a program, governed by principles of nondisclosure and confidentiality, that works with private-sector facility-locating functions to assess need and impact.

Appropriate federal and state actions, and their associated expenses, need to be fully understood in the network context. For example, dredging by the U.S. Army Corps of Engineers is fundamental to waterborne commerce, so one concerned with overall freight efficiencies might ask, "Why are the federal dollar commitments to this critical function diminishing rather than expanding?" The energy efficiency and reduced emissions associated with waterborne commerce alone should justify public investment as a strategic move, not to mention the critical role ports play in international commerce.

All affected states need to focus on federal Water Resources Development Act (WRDA) bills and place pressure on Congress to appropriate the dollars to accomplish dredging in an environmentally sound fashion.

Outsourcing to the Private Sector

There is growing recognition that a well-balanced and diversified multimodal transportation system will be required to provide future generations with the opportunities for prosperity that have been a hallmark of the American economic experience. In an era of economic slowdown, dwindling Highway Trust Fund monies, decreasing state highway maintenance and improvement funds, and overall public-sector financial constraints, public-sector cooperation with the private sector is becoming increasingly prevalent as a source of both capital and, in some cases, as a source of funds for long-term maintenance or operation of infrastructure.

Public-private partnerships are emerging as a viable way to leverage public investment.

Public-private partnerships are emerging as a viable way to leverage public investment in transportation to meet the needs of an expanding economy dependent on freight mobility. PPPs are generally considered to be mutually beneficial (win-win) opportunities, and freight rail in particular, once the backbone of the freight transportation system, is emerging in public transportation planning as a preferred means to get more goods and materials to market.

Historically, public investment in private business has been limited, and those cases that have been pursued have been undertaken with caution. The recent financial crisis and taxpayer bailouts of both domestic auto manufacturers and banks are a case in point and underscore the sensitivities associated with public funds being directed to the aid of commercial enterprise. The current discussion around PPPs to enhance freight rail infrastructure, however, may be better fashioned as another case of outsourcing traditional public-sector transportation functions to the private sector based on the determination that a mutually beneficial partnership is a better use of public funds than the alternative – in this case, additional expenditures in highway capacity.

SPECIFIC SOLUTIONS

Technology and Operations

Texas should conduct a forward-looking assessment of likely emerging technology and operational practices in response to changing logistic conditions. The result of this assessment should be used to understand how these trends could affect the public-sector role in providing and facilitating goods movement. It is equally important to understand that some, if not most, significant and transformative changes will not be well anticipated. In order to best respond, a statewide freight transportation steering committee needs to be established that can assist TxDOT in understanding the developments occurring in technology and operations and what pressures motivate these developments.

All modes are investigating new technologies, and where a technology strategy offers improved safety, efficiency, or competitive advantage, firms are employing them to good advantage. The trucking industry has embraced a host of position location, routing optimization, and communications strategies to better manage their assets and more effectively serve customers. These mobile communication systems include decision support systems, automatic vehicle/equipment identification systems, electronic data interchange, bar coding, and imaging systems.

The railroad industry has begun implementing various versions of positive train control (PTC) technologies used to enhance the command and control of their assets on the rail network. The Federal Railroad Administration (FRA) is encouraging use of PTC as a safety enhancement, justified by inherent productivity gains associated with operating more trains on a given line. But the railroads, a very safe industry by highway standards, make an economic case against a broad mandate that requires PTC implementation, maintaining that neither the safety benefits nor the productivity gains justify the enormous costs. Congress has taken initial steps in the 2011 spending package to drop funding for the FRA's Railroad Safety Technology Program that mandated PTC implementation on select lines by 2015. Whatever the outcome of these discussions, PTC will likely appear on U.S. railroads only selectively and incrementally.

Macro-Level Decision Making

A corollary to the relativistic notion that being better than the competition is more meaningful, in practical terms, than being judged "good" by some absolute standard is that providing relatively superior infrastructure and relatively efficient network systems will attract users, induce economic growth, and foster prosperity. Thus, staying ahead of the competition (i.e., other states) is as important for Texas as it is for a freight transportation provider.

Major, proactive decisions need to be made that enable economic development conditions to emerge. An example would be the "Texas Superport," which in concept would link the appropriate Texas sea ports to themselves and with other elements in the state's transportation system to improve the overall freight transportation system and its connections, enabling Texas to become a beneficiary of the expanded Panama Canal. The proposed I-69 corridor along the Texas coast from Brownsville to Texarkana would serve well in this capacity and should be considered as an investment in the future competitive positioning of Texas.

Texas has an extensive and geographically favorable coastline, with several excellent ports and other locations well suited to expand the state's maritime trade base. The Panama Canal expansion and the predictions for increased containership traffic through the facility opens up the possibility – at least on a longer-term basis – for increases in foreign trade through the state. The geographical location of the Panama Canal places ships transiting west to east almost due south of Miami, Florida – more than a day's sailing distance to the Texas coast. The large markets in Texas notwithstanding, for significant trade diversions to occur to the state, not just adequate but exceptional transportation infrastructure must be in place to supplant the geographic advantage of the East Coast by providing lower cost and faster linkages to Midwestern markets. Currently, these superior routes do not exist.

Additionally, there are several physical obstacles for Texas ports to overcome in anticipation of Panama Canal trade; expansion of the Panama Canal is necessary for greater flow of goods to the state but is not sufficient. There are at least three principal obstacles:

1. First, there is no port in the state with sufficient channel depth to accommodate the 52-foot draft of the mega-container ships now coming online. The Port of Corpus Christi has received WRDA authorization to dredge but no supporting appropriation. The Port of Houston has no such authorization and may self-fund dredging and seek federal reimbursement at a later date.

2. In addition to matters of draft, the landside connectivity of most Texas ports needs additional attention. For many ports on the lower reaches of the Texas coast, the sheer distance to the markets of interest remains an impediment to garnering additional volume. The railroads have shown limited interest in transporting intermodal containers from the southern ports, and the driving distance results in logistical and economic hurdles that do not beset many ports on the eastern seaboard.
3. Finally and perhaps most significantly, entrance to the Atlantic from the Panama Canal places vessels south of Miami, Florida, more than a full day away from the Texas coast. So, beyond the growing population and markets of the state, unless there are compelling logistical reasons for sailing through the Gulf of Mexico and back, the commitment of maritime assets will likely be directed to the ports on the eastern seaboard.

Planning and Investment

The state needs to strategically address the intrinsic link between transportation efficiency and economic development. As a result, a freight advisory committee should be formed whose goal is to develop a closer and more efficient linkage to the Mexican economy and Canada. Mexico's proximity to Texas is among the most important geographical advantages for the state. While Texas is an east-west crossroads with important links to California and the East through New Orleans, it is the single state with major access to the Mexican industrial heartland and in that capacity serves as the conduit to most of the Canadian business interests with Mexico.

The geo-political implications of this are enormous. By creating economic development in Mexico (rather than China), increased commercial relations with Mexico will:

- stem the flow of money abroad,
- create good jobs in Mexico and slow the rate of illegal immigration into the United States from Mexico and Central America,
- reduce the cost of goods for U.S. consumers, and

- put Texas in the position to gain economic advantage and grow through mutually advantageous economic ties.

CONCLUSION

Freight transportation is a private-sector undertaking with cost-minimization as a central goal. A clear understanding of the characteristics, motives, constraints, and goals of the goods movement industry is fundamental to developing a strategic approach for the public sector's critical facilitating role. The goods movement industry is highly competitive, profit oriented, and generally opposed to government regulations that restrict its operating freedom. Competitive advantage, once established, is fiercely guarded, and the closely held data that would help public-sector planning functions are either not collected or not disclosed. Both the public-sector and private-sector freight transportation service providers are concerned with public and worker safety, but the private sector's focus is intensified by the potentially devastating economic consequences of negligent operating practices. Hence, risk management and insurance coverage are major issues along with the required compliance with safety regulations. Environmental regulation creates a similar contrast in point of view – the public sector seeks to protect the environment and its occupants, while the private-sector goods movement industry seeks beneficial regulation that does not adversely impact its bottom line.

The linkage between efficient and nimble freight transportation networks and a region's economic health becomes more obvious as freight performance measures deteriorate and commercial activity migrates to locations better suited to support goods movement. But the fact that logistics costs are passed along to the customer or consumer means that relative superiority in goods movement is more pertinent to freight transportation than absolute measures of efficiency. Strategically, from the state transportation planning perspective, this relativistic notion of beating the competition rather than the statistics should be at the heart of programs aimed at keeping Texas among the preferred commercial and business settings.

A beginning step could include an introspective evaluation of the state's strengths, weaknesses, opportunities, and threats (a SWOT analysis):

- Strengths:
    - Texas has a fairly good transportation system in place
        - Excellent roadways
        - More rail miles than any other state
        - The leading maritime state in the nation
    - Geography favors Texas
        - Centrally located
        - Mild climate
    - Texas has business-friendly laws/taxes
- Weaknesses:
    - Everything is big in Texas – very large space and lots of lanes miles
    - Texas has a rapidly growing population
    - Texas has little anticipatory freight planning
- Opportunities:
    - Expand the state's maritime advantages
    - Facilitate trade with Mexico
    - Understand the opportunities that come with being at the crossroads of the southern United States
    - Take advantage of the potential of the North American Free Trade Agreement and the freight corridors that could result
- Threats:
    - Other states, particularly on the East Coast, may take trade that could otherwise come to the United States through Texas
    - Adjacent states may take actions that facilitate goods movement
    - Traffic congestion may drive away business
    - Deteriorating systems and infrastructure can erode the state's competitive stance

A concluding set of thoughts should include the recognition that positioning Texas for future economic health and prosperity must include strategically conceived, planned, and executed steps that support the state's freight transportation networks and the efficient interaction of those networks. An expansive view of the goods movement industry should involve knowledge from far outside our borders and the recognition that global impacts are often fostered by very local actions. Working with other states to develop a more comprehensive vantage point relative to freight networks can help Texas build on its substantial geographical, business, and human resource advantages to become an increasingly important force in international trade and thereby ensure economic health and prosperity for future Texans.

ABOUT TTI

This research brief was prepared by the Texas Transportation Institute (TTI), a part of The Texas A&M University System and an agency of the State of Texas.

TTI's program of practical, applied research helps hundreds of sponsors address a range of transportation challenges. For example, through decades of research in just the highway area – planning, design, construction, maintenance, safety, and operations – virtually every mile of roadway in Texas has been positively impacted by some aspect of the TTI program. Through research, development, and technology transfer, TTI is helping to meet the transportation needs of tomorrow.

Our mission is to solve transportation problems through research, to transfer technology, and to develop diverse human resources to meet the transportation challenges of tomorrow.

Texas Transportation Institute

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The SRP program is jointly guided by a three-institution consortium comprised of the Center for Transportation Research at The University of Texas, the Texas Transportation Institute at Texas A&M University, and the Institute for Multidisciplinary Research in Transportation at Texas Tech University.

CENTER FOR TRANSPORTATION RESEARCH

An Integrated Approach to the Maintenance and Rehabilitation of Pavements and Bridges

TxDOT Strategic Research Brief #6:

Examine proper funding strategies and levels for maintenance of pavements and bridges in Texas-strategically allocated funds for pavement maintenance and rehabilitation

Zhanmin Zhang
Randy B. Machemehl
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April 15, 2011

"Gentlemen, we are out of money. We shall have to think."

—Address to Parliament by Winston Churchill

Introduction

The budget shortfall for Texas for 2011 is as high as $27 billion. The funding for TxDOT comes primarily from the revenues generated from the motor fuel tax. This tax has not been incremented since the early 1990s. Therefore, the purchasing power has significantly eroded over the last two decades. Furthermore, the state has experienced a significant increase in population. However, this population growth has not translated to additional revenue for TxDOT, due to the increased use of more fuel-efficient vehicles. In other words, there are more cars on the road but they are contributing less money towards the maintenance of our highways.

As demand continues to grow for Texas highways, the consumption rate of our roads increases, but there are fewer dollars to maintain them with. Our highways represent billions of dollars of investment in our transportation system. Not only do we risk losing a significant amount of our highways, but we are also putting Texans' lives at greater risk. TxDOT must develop new and innovative ways to ensure that our highways will keep helping Texas maintain its economic competiveness with a safe, reliable, and economical highway transportation system.

Infrastructure preservation activities are ongoing processes that are required for the entire TxDOT road network. TxDOT maintains approximately 192,000 lane miles of paved roadway, including more than 50,000 bridges. For such a geographically extensive network, the preservation activities result in significant financial needs. With the growing needs and limited resources, TxDOT needs to rethink the way it conducts business to optimize its pavement and bridges infrastructure needs.

In a recent study carried out to evaluate the pavement maintenance needs of Texas by year 2030, it was estimated that in order to match up with the Texas Transportation Commission (TTC) goal of preserving the asset value of all pavements by maintaining a 90 percent "good" or better pavement condition goal, the pavement preservation needs were about $3.5 billion per year on average.

Figure 1 illustrates the annual preservation needs to attain and maintain 90 percent “good” or better condition from year 2009 to 2030. Based on the funding projection conducted by TxDOT, the available funding in the next 20 years is clearly insufficient to meet the total needs of pavement infrastructure to achieve and maintain the 90 percent “good” or better pavement condition goal.

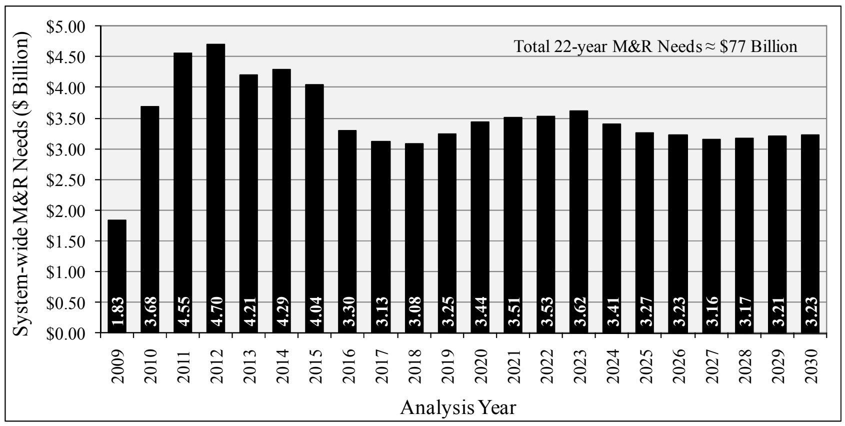

Figure 1. Annual M&R Needs to Attain and Maintain 90% “Good” or Better Condition

More specifically, with the current funding allocations and projections, the “good” or better pavement score will drop below 80 percent by year 2012; and by year 2018, the score will drop below 50 percent. The “good” or better pavement condition scores are 65.43, 33.72, 20.65, 13.56, and 6.94 percent for FY 2015, FY 2020, FY 2025, FY 2030, and FY 2035, respectively, as shown in Figure 2.

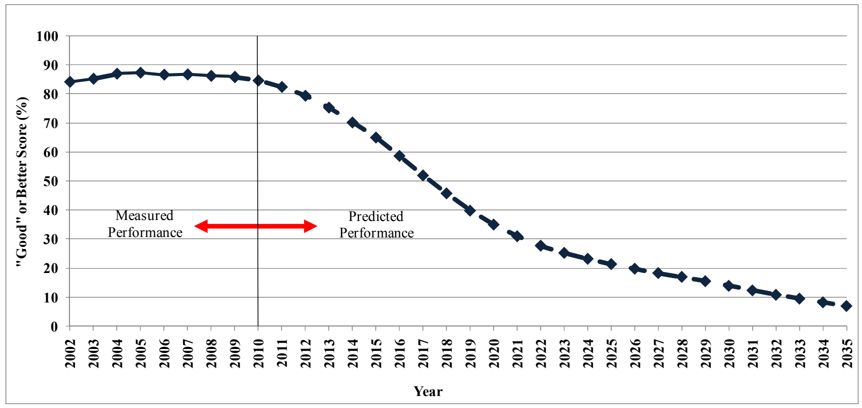

Figure 2. Predicted Pavement Performance Trend for FY 2010 to FY 2035 Based on TxDOT Funding Projections

The discussions so far make clear that funds are insufficient to pay for the maintenance and rehabilitation work that is required to keep the overall condition of the state-maintained highway system at the current target condition level. This situation has raised the prospects for reviewing the state's highway infrastructure needs by classifying the transportation facility and service needs by interest and use.

Problem Statement

The efficiency of Texas's transportation system, particularly its highways, is critical to the health of the state's economy. Businesses are increasingly reliant on an efficient and reliable transportation system to move products and services. However, the gap between projected revenues and minimum investment needs averages several billion per year. Under this situation, finding proper funding strategies and levels for maintenance of pavements and bridges in Texas requires fresh perspectives by looking at the problem not only in terms of maintenance itself, but also in terms of finance and operations.

1) Increasing Travel Demand

Despite the current economic downturn, population increases and economic growth in Texas over the past two decades have resulted in increased demands on the state's major roads and highways.

Texas's population reached 24.8 million in 2009, an increase of 46 percent since 1990. The state's population is expected to increase to 31.8 million by 2030. Vehicle travel in Texas increased 45 percent from 1990 to 2008—from 162.2 billion vehicle miles traveled (VMT) in 1990 to 234.6 billion VMT in 2008. By 2025, vehicle travel in Texas is projected to increase by another 40 percent.

2) Deteriorating Infrastructure

Pavement and bridge conditions will become significantly more deteriorated in the future under current funding projections. The TRIP report, "Future Mobility in Texas: Meeting the State's Need for Safe and Efficient Mobility," finds that throughout Texas, 11 percent of state-maintained roads and highways provide motorists with a rough ride. The Center for Transportation Research (CTR) at The University of Texas at Austin estimates that under current funding levels the share of state-maintained roads and highways that have pavements in "good" or better condition will decrease from 86 percent in 2010 to 21 percent by 2025.

The same report estimated that 3 percent of Texas bridges are structurally deficient, meaning that there is significant deterioration to the bridge deck, supports, or other major components. An additional 14 percent of bridges are functionally obsolete. These bridges no longer meet current highway design standards, often because of narrow lanes, inadequate clearances, or poor alignment with the approaching road.

3) Funding Gap

According to the findings from the recent study conducted by the Texas 2030 Committee, Texas will need \$74.9 billion in order to keep its road at the 2010 condition in the next 25 years. It is also reported that the funding gap continues to increase as tax revenues decline and the population of the state increases each year. The Committee estimated that \$270 billion is required between 2011 and 2035 in order to continue Texas's transportation system with its 2010 condition.

4) Conclusion and Restatement of Solution

Therefore, it is important that a strategic plan address the deterioration of infrastructure and the declining funding for transportation as a whole.

Ideas for Generating Transportation Funds

Over the last decade transportation agencies have seen a considerable decrease in available funds to maintain the highway infrastructure. Most states are searching for alternative ways to fund transportation needs. The National Surface Transportation Infrastructure Financing Commission pointed in its 2008 interim report that the current levels of taxes are inadequate for funding the maintenance, let alone the improvement, of the system. It also indicated that the current funding mechanisms and levels of revenue were not closely linked to the actual usage of the transportation system, thus allowing the demand and costs to grow faster than revenue. Following are a few ideas to generate transportation funds:

1) Increasing Fuel Taxes

Although the federal gas tax has not been changed from 18.4 cents per gallon, at least 15 states have increased the state gas tax. But experts agree that further increase in gas tax is going to be politically difficult. In addition, the buying power of fuel tax has fallen due to inflation and reduced fuel consumption due to fuel-efficient cars and cutbacks on driving as prices have increased. Many believe that linking user payments with actual road use through tolls, congestion fees, and VMT charges is more logical and would have greater public support.

2) Raising Vehicle Fees

Although a registration fee adjustment is very promising both for short-term and long-term revenues, initiatives to increase registration fees in some states have faced severe opposition. For example, Idaho was forced to abandon its proposal to raise vehicle fees after a critical reception from the public and legislators. But some states are clearly considering vehicle registration fees and other highway user taxes a part of the revenue. The National Surface Transportation Infrastructure Financing Commission has identified vehicle registration, heavy vehicle user taxes, sales taxes, and tire taxes as potential transportation funding mechanisms.

3) Public-Private Partnership

Commonly known as PPP, public-private partnerships are collaborations between governments and private companies that aim to improve public services and infrastructure by capturing the efficiencies associated with private sector involvement while maintaining the public accountability of government involvement. The Office of Innovative Program Delivery (IPD) under the FHWA defines PPP for "new build facilities" and "existing facilities." IPD categorizes PPP for new build facilities as "Design Build," "Design Build Operate," and "Design Build Finance Operate," and for existing facilities as "O&M Concession" and "Long Term Lease."

Over the last 15 years numerous public-private partnerships have developed on new and existing facilities along new terms of agreement. This private interest attests to the fact that private financing is a plausible solution to the funding gap faced by transportation agencies.

4) Direct User Fees

As states consider new mechanisms to fill in funding gaps, one of the areas that should be considered is to link the user payments more closely to actual road use. Mark Florian, the head of investment banking at Goldman Sachs, told Congress in 2008 that the current funding mechanism is not directly linked to the use of the transportation system, allowing demands and costs for a given asset to grow faster than the revenue that funds it. Examples of direct user fees include tolling, congestion pricing, and VMT.

a. Tolling

In 2004, state and local governments used $6.6 billion in toll revenues for highway investments, which is 7 percent of total revenues used for highways at state and local level. Currently, tolling on existing roads is challenging and is mostly prohibited on the inter-state system. Experts believe that tolling on new roads or when adding additional lanes holds potential for generating new revenue. Texas has decided to refrain from tolling existing lanes but is funding new limited access highways partially through tolls. Several other states are considering it as a policy. Florida has derived as much as 11 percent of its revenue from tolls.

b. Congestion Pricing

Congestion pricing is a funding mechanism that seeks to assess vehicles for the cost they impose on society, which may include time cost, congestion, and other variable costs such as environmental and governmental. The fees can be based either on time of day or on the level of congestion. Experts believe that these pricing schemes affect congestion in several ways, including number of trips, total miles travelled, routes taken by travelers, times of trips, carpooling, and transit usage. The most common methods are facility pricing, road pricing, and cordon pricing. Orange County, California, provides an example of road pricing operated by a private firm. The tolls are based on time of day and revenues in excess of $30 million were received in 2004. The program in San Diego, California, has generated revenues up to $750,000 per year in operating costs and also provides $60,000 per year for enforcement.

c. Vehicle Mile Travelled (VMT) Charges

The Oregon Department of Transportation launched a pilot program in 2006 to assess the potential feasibility of replacing the gas tax with VMT charges collected at gas stations. The pilot program found VMT to be a successful replacement to the current gas tax system. Ninety-one percent of participants agreed to pay VMT charges instead of gas tax. The findings also show that concerns with privacy can be protected. Congestion pricing and other pricing options are also viable under this scheme.

Proposed Solution Framework

In this research, an integrated approach is proposed to solve the funding gap problem of transportation infrastructure preservation. In this proposed approach, a multi-tier infrastructure system is established. Resources will be allocated among tiers according to their level of service and performance goals. Moreover, a usage-fee-based public finance system is also included in the proposal. The proposed integrated approach will maintain Texas's economic competitiveness and support sustainable economic growth.

Benefits

Proper funding strategies and levels for maintenance of pavements and bridges in Texas will be critical for the efficiency of Texas's transportation system. A sound highway infrastructure will help sustain and boost the economic growth in Texas. Adequate maintenance strategies for the network, coupled with proper funding apportionment, will prevent the pavement and bridge infrastructure from deteriorating into unacceptable conditions in the future. A strategic plan that addresses the projected funding gap is of paramount importance to optimize the response to pavement and bridges infrastructure needs.

Specific Solution

The proposed idea is an integrated approach to find the proper funding strategy and level of existing infrastructure maintenance through the implementation of integrated systems, services, and projects. This approach includes regional operations collaboration and coordination of maintenance, operation, and financing activities, as illustrated in Figure 1. The proposed integrated approach aims at maintaining Texas's economic competitiveness and support Texas's sustainable economic growth.

1) Multi-Tier Systems

A single-tier system can work very well if the resources are sufficient to cover the entire network. However, when resources are constrained, hard decisions must be made in terms of prioritizing elements of the road network. This process is usually accomplished by establishing a multi-tier system based on the relative importance of the road links in the network, where the resources are tilted more towards the road group or tier that is deemed to be the most important.

To conduct the multi-tier analysis, the first step is to define the tiers, using criteria such highway functional class, ADT, truck ADT, etc. As of now, a proposed three-tier system was initially selected for conducting the preliminary analysis. The three tiers are shown in Table 1, along with the level of service and performance measures.

Table 1. Systems and Level of Service

System	Service	Measures			
		Safety	Efficiency	Dependability	Comfortability
Backbone	Premier	X	X	X	X
Backup	Standard	X		X	
Connection	Basic	X			

As illustrated in Figure 3, the "Backbone" system is defined as corridors that are essential to the economy of Texas. Examples include Interstate 10 through the southern part of the state, Interstate 20 from east of Dallas/Fort Worth to Interstate 10 near Midland, along an extended Interstate 27 through western Texas, and a new terrain corridor along the northern Texas border paralleling sections of Interstate 30 from the Arkansas line at Texarkana to Fort Worth, US 287 from Fort Worth to Amarillo, and Interstate 40 from Amarillo to New Mexico. The level of service of the "Backbone" system will be defined as "Premier," meaning that all measures (safety, efficiency, dependability, and comfort) should be fully satisfied. The "Backup" and "Connection" road systems are defined as supplements to the

Backbone systems. The required level of services of those two systems is not as strict as that of the "Backbone" system.

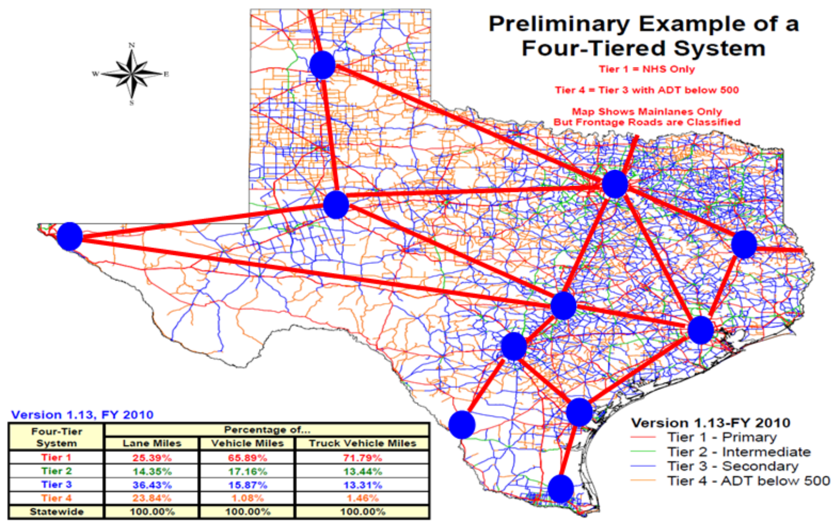

Figure 3. Illustration of the "Backbone" System

2) Define the Level of Services and Performance Measures

Performance measurement is a process for evidence-based decision-making and forecasting, as well as monitoring progress towards long-term goals and objectives. Measuring performance is a way to gauge the impacts of the decision-making process on the transportation system.

The performance measures used in this proposal focus on a broad set of transportation goals, including safety, efficiency, dependability, and comfort. One means to support a performance-based level-of-service approach to infrastructure maintenance management is to establish a few overarching goals and identify supportive performance measures within each goal area that TxDOT could incorporate into its transportation planning process.

3) User Fees

This proposal suggests that user fees and user-fee-backed public finance be considered as potential solutions to ensure a dedicated revenue source for transportation infrastructure and to provide congestion relief through demand-based pricing. Direct user fees, or tolls, on the usage of the "Backbone" system is a promising solution to Texas's challenges of insufficient funding and congestion in the transportation sector. Tolling offers a dedicated revenue source that would be usage-based, more reliable and, if appropriately structured, less susceptible to political intervention. With a dedicated revenue source in place, financing Texas's roadways would become much easier through the issuance of revenue bonds.

An important collateral benefit to rationing highway space with direct user-fees is the potential to relieve congestion, keep the transportation system operating at higher speeds and efficiencies, and achieve environmental benefits through dynamic, demand-based pricing. Tolls would be set to rise and fall dynamically throughout the day, varying with fluctuations in user demand. For example, at midnight when the road is not heavily used, it may very well be possible to make all lanes free. On the contrary, at 8:00 a.m., in morning rush hour when traffic is at its worst, the toll may rise to $5 or higher. At 3:00 p.m., when traffic is relatively light, the toll might fall to $2.

Proposed Areas of Research

In order to implement a sound funding and maintenance strategy, we need to focus the study on the integrated approach outlined previously. The issues that need to be addressed immediately are as follows.

1) Define the Multi-Tier Networks

The following questions need to be answered in order to define the multi-tier networks under the strategic maintenance plan.

a. What are the economic centers in Texas?

Because the objective of the program is to support Texas's economic growth, defining the networks should start by identifying economic centers across the state. These form the primary nodes of the "Backbone" network.

b. How to identify corridors connecting economic centers?

Once the nodes are clearly identified, the corridors can be defined by examining the existing travel routes and determining whether new routes are necessary. These routes form the corridors connecting the economic centers.

c. How to identify the tiers in the highway network?

As part of the proposed approach, different levels of service have to be set for different tiers. Therefore, classifying the networks into tiers is necessary. The primary tier or the backbone will be maintained at the highest standard. The second and third tier will receive less maintenance. Studies need to be carried out to decide which links will form the first, second, and third tiers.

2) Determine Usage Fees

If one portion of the network is maintained better than other portions, it will definitely attract a larger portion of travelers, ultimately leading to congestion. In order to develop a mechanism to control usage, the following questions must be answered.

a. How to Determine the Usage Fees for General Usage?

The primary tier has been proposed to charge a flat usage fee for general use and additional fees for usage during rush hours, as illustrated in Table 2. Studies need to be carried out to determine the flat usage fee for using the "Backbone" system in order to make the primary tier a self-sustained system.

b. How to Identify Extra Fees for Rush Hour Usage?

In order to control congestion during rush hours, a dynamic usage fee should be considered for the "Backbone" systems. Further studies need to be carried out to determine how the dynamic usage fee should be developed and implemented for rush-hour usages.

Table 2. Proposed Usage Fees

System	Service	Controlled Usage	
		Fee for Usage	Extra Charge for Rush Hour Usage
Backbone	Premier	A fee in addition to the normal registration fee	X
Backup	Standard	Normal registration fee	
Connection	Basic	Normal registration fee	

3) Develop Appropriate Maintenance Strategies

The impetus of the proposed strategic maintenance approach is that the highway network in Texas will be maintained by tiers where each tier has a different level of service in terms of safety, efficiency, dependability, and comfort. This implies that the maintenance strategies or treatments will be different for different tiers. Studies will have to be conducted to develop appropriate maintenance strategies for each tier, considering the impact of these strategies on the measurements that are used to define the level of service, as illustrated in Table 3.

Table 3. Illustration of Maintenance Strategies

System	Service	Treatments			
		Major Repair	Minor Repair	Maintenance	Other
Backbone	Premier	X	X	X	Eliminating bottlenecks, etc.
Backup	Standard	Reduced Frequency	X	X	
Connection	Basic		Reduced Frequency	X	Reduced speed limits, etc.

Conclusions

Texas pavement and bridge conditions will become significantly more deteriorated in the future under current funding projections. In this research, an integrated approach is proposed to solve the funding gap problem of transportation infrastructure preservation. In the proposal, a multi-tier infrastructure system is needed to optimize the resource allocation among the network. Moreover, a usage-fee-based public finance system is also proposed for using the “Backbone” system. The proposed integrated approach is expected to help maintain Texas’s economic competitiveness and support Texas’s sustainable economic growth. More specifically, the benefits of the proposed research include:

1) The user is given the flexibility to choose from three levels of service and pays an extra fee only if the premier service is chosen;
2) The extra fee for the backbone system will require a reduced amount of appropriated funds and could potentially be self-sustainable;
3) With a backbone system that could potentially be self-sustaining, funding can be reallocated to better address the needs identified for the backup and connection systems;
4) The implementation cost is low; and
5) It will make Texas the leader in reconfiguring and maintaining highway networks.

Texas Department of Transportation

Providing safe, effective, and efficient movement of people and goods.

Strategic Research Program – Research Brief

The Interstate Shield: Time to Reconsider a Roadway Icon?

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SRP-RB 007 prepared for

Research and Technology Implementation Office
118 East Riverside Drive
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1 June 2011

Strategic Research Program Purpose

The Texas Transportation Commission established the Texas Department of Transportation (TxDOT) Strategic Research Program in 2011 to assist the department with its number-one goal: preparing for the future. This series of research briefs is intended to identify and frame transportation challenges Texas will face over the next 10 to 30 years. In support of that goal, the briefs attempt to spur discussion within and outside of TxDOT to address issues that TxDOT's stakeholders, interest groups, the Texas Legislature, TxDOT Administration, or the Transportation Commission foresee affecting the efficiency and viability of the state's transportation system.

Using current literature, interviews, and other sources, briefs are meant to provide the reader with an overview of the subject and emphasize the strategic elements of a topic that may need further development, either focused research or internal TxDOT actions. The briefs themselves are not intended as a detailed examination of current or planned TxDOT activity.

This research brief reviews the impact of the federal interstate highway system in Texas and looks for possible low-cost ways to deal with the expanding unmet and unfunded system needs.

Figure 1. The interstate shield.

The Interstate Shield: Time to Reconsider a Roadway Icon?

In 1945, there were 1.7 million vehicles registered in Texas. Just five years later, the number had grown to more than 3 million vehicles. The country had been considering the need for a national system of roadways since the 1930s. Change was palpable: personal vehicle ownership was rapidly expanding, and growing families searched for better living conditions and circumstances. After years of debate, the U.S. Congress approved the National Defense Highway Act in 1956 to provide a national network of roadways to connect cities and to accommodate the rapidly growing number of new personal vehicles and trucks carrying goods to consumers who were increasingly moving from cities to suburbs. This was the Interstate Highway System, symbolized by the interstate shield (Figure 1).

No state had a greater stake in its success or could anticipate greater benefits from the new Interstate Highway System than Texas (Beaumont et al. 2006). Nearly 3,000 miles of the 40,000-mile system were slated for Texas. Undoubtedly, the system has been a significant influence on the state's population growth and economic development. As the years have passed, demands have grown for additional interstate miles. Figure 2 shows the modern Interstate Highway System in Texas.


Figure 2. Map of Texas interstate highways.

Today, more than 21.6 million vehicles are registered in Texas. Demands reflect rapidly growing areas, increased international trade, and the perception that opportunities for economic development are diminished in areas without interstates. However, the necessary resources do not appear available to pay for adding more roads with that iconic shield. Is it time to consider additional approaches to building the more than 4,000 future interstate miles that have been designated by the U.S. Congress but remain unbuilt (Weiss 2009), including the future I-69 through Texas?

Introduction

This research brief provides an overview of the history of interstate development in Texas, and its past and present impacts on the state's growth and economy. It describes how the private sector makes decisions about where to locate, how those decisions relate to transportation, and how changes in transportation could affect that process. Finally, this research brief suggests some potential actions that could possibly help deal with the designated but unbuilt future interstate highways in Texas and the rest of the country.

Current Situation

Simply put, demand for interstate and controlled access highways or freeways is much greater in Texas and the rest of the country than can be met today or by the currently forecast state and federal resources. The state and federal transportation communities are currently discussing all roadway funding (not just the interstate system), with multiple reports quantifying the demands and the impacts of not providing the additional transportation improvements. Numerous federal commissions and committees – appointed by governmental bodies, transportation organizations, trade associations, and various esteemed non-profit or academic institutions – have deliberated on transportation needs and resources.

Among these are two Texas-based research efforts directed by the 2030 Committee, a group of state business leaders and transportation experts appointed by the chair of the Texas Transportation Commission. The first effort, completed in 2009, projected unmet needs (2030 Committee 2009). It estimated that $270 billion would be required over the next 20 years to keep up with transportation demands in Texas. The second effort, prepared in 2011, updated the needs and possible solutions (2030 Committee 2011). It concluded that transportation needs are still significant despite the recent economic downturn and offers possible policy solutions.

Figure 3. U.S. highways proposed to become I-69 (Alliance for I-69 Texas 2011).

Many major, locally organized efforts are calling for additional interstate highway construction, or designation, in Texas and elsewhere. The primary movement in Texas is the Alliance for I-69 Texas, which began 17 years ago and includes in its membership a collection of cities, counties, port authorities, local economic development organizations, chambers of commerce, and businesses in the 34 counties along a now congressionally designated corridor. The corridor itself reaches from several points along the Texas-Mexico border, through Houston, and north to Texarkana, and is part of a planned roadway that continues north to Indiana (Figure 3).

These groups are seeking improvements to the interstate system for a variety of reasons. The Alliance for I-69 Texas sees the benefits of I-69 as safety improvements, economic development, trade efficiency, ease of travel, and connection of the Lower Rio Grande Valley to the rest of Texas (Alliance for I-69 Texas 2011). This brief attempts to address only the subject of economic development in the hope of offering lower-cost options that could produce value sooner.

Historical Overview

The interstate system was designed to be a point-to-point system, connecting all cities in the nation with a population of more than 50,000. Most of the larger Texas cities met the criterion in 1956: Dallas, Fort Worth, Austin, Houston, San Antonio, and El Paso. The interstate routes were based on recommendations from the states and had been laid out as early as 1944. The Department of Defense reviewed the final interstate map included in the 1956 legislation, but final route decisions, including where interstates should be built and whether or not they should have frontage roads, were left to the state highway departments and their governing bodies – in Texas, the Highway Commission.

The 1956 act also set geometric and construction standards, and required that the American Association of State Highway Organizations (AASHO) (the precursor to the American Association of State Highway and Transportation Officials) develop a guide for implementing those standards. Texas was an active AASHO member and well prepared to begin implementing the plans.

By 1962, the interstate system in Texas included the highways noted in Table 1 – which were either open, under construction, or planned, with final routes determined by the Highway Commission.

Table 1. Highways that made up the interstate system in Texas in 1962.

Miles	Description
879	I-10 from the Louisiana border to the New Mexico border north of El Paso
634	I-20 from the Texas border east of Marshall through Dallas-Fort Worth to a point southwest of Pecos, where it joins I-10
240	I-30 from Texarkana to Dallas-Fort Worth where it joins I-20
492	I-35 from the north Texas border to Laredo (both I-35E and I-35W)
142	I-37 from San Antonio to Corpus Christi
182	I-40 from the Texas/New Mexico state line to the Texas/Oklahoma state line
14	I-44 from Wichita Falls to the Texas/Oklahoma state line
286	I-45 from Dallas to Galveston, passing through Houston

Of the urban freeway loops, only Loop 610 in Houston was approved by 1962, but others in Dallas, Fort Worth, San Antonio, and El Paso were approved in the late 1960s and early 1970s. I-27 from Amarillo to Lubbock was added in 1975.

Texas had nearly 2,500 miles of highways, and some could be upgraded to new interstate standards relatively easily, such as I-45 replacing US 75 between Dallas and Houston, I-35 replacing US 81, and I-40 replacing US 66 across the top part of the state. The 1956 act declared that the interstate system would be completed by 1972. It took 36 years for completion of the state's interstate system in Texas, which included the additional I-27 link added in 1975.

Dewitt Greer, who led the Texas Highway Department from 1940 to 1967, was one of the strongest advocates for construction of "interregional superhighways." He is also credited with promoting the idea of the frontage road system, which is more predominant in Texas than other states. He believed that the new interstate roadways should serve local and "interregional" traffic as well as long-haul through traffic. This led to the state's more than 4,500 miles of frontage roads along interstate highways and freeways. These ancillary roadways, known as feeder roads, service roads, or access roads, led to large-scale economic development. The highway system alone has contributed $2.8 trillion to the Texas state economy over the past 50 years and more than $100 billion each year since 2004 (Beaumont et al. 2006). The estimate reflects increased productivity for business, resulting in a better competitive position for Texas products both domestically and internationally.

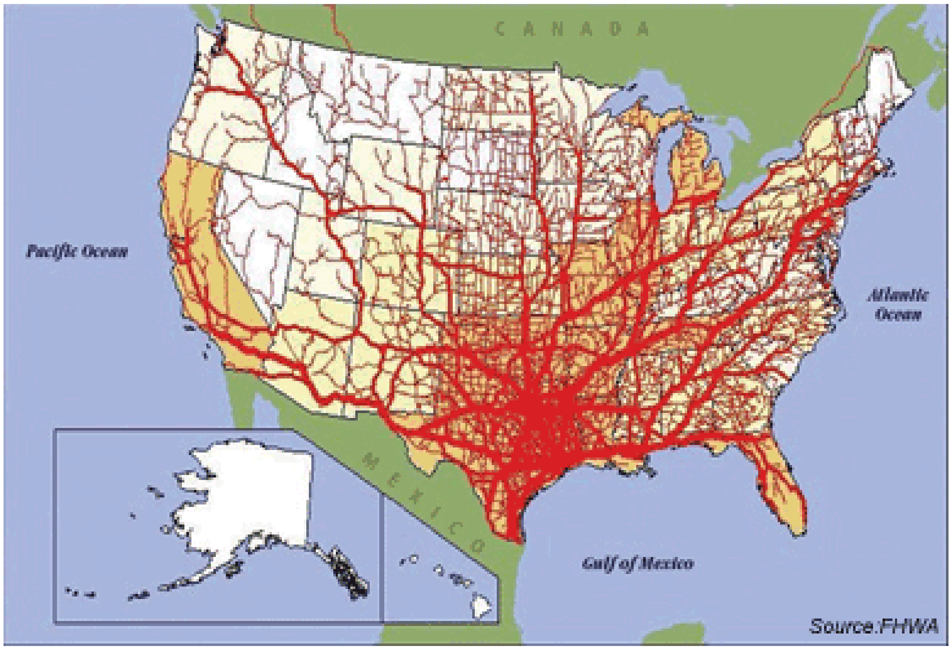

Figure 4. Map of freight volume shipped through the United States (Palacios 2005).

The Texas portion of the interstate system represents only 2 percent of all lane miles in the state, yet it accounts for more than 20 percent of all miles driven annually. Federal studies have shown that Texas has the highest truck volume in the nation as a percentage of all vehicle miles traveled – and more than 45 percent of the state's tractor-trailer operations are on the interstate system (Beaumont et al. 2006). Freight patterns are shown in Figure 4.

Evolving Program

Since the first section of Texas interstate was let to contract in 1956 for a segment of I-45 near Corsicana, and the last segment of I-27 between Lubbock and Amarillo was completed in 1992, the system of roadways has matured. It has experienced nearly continuous maintenance and rehabilitation, and additional demands for expansion. However, the final appropriations for the interstate construction program were made in 1996, even though in 1995 Congress began identifying previously designated high-priority corridor programs as future interstates. Currently, Congress has identified more than 4,000 miles of such future interstates (Figure 5) but has not provided the dollars to build them.

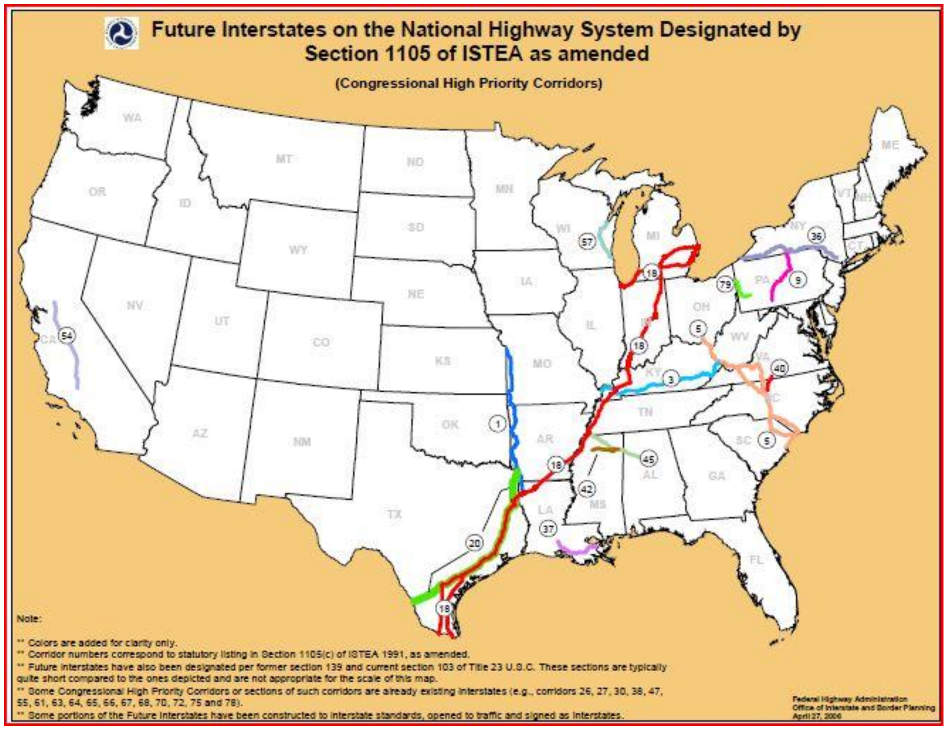

Figure 5. Future interstates on the National Highway System designated by Section 1105 of the Intermodal Surface Transportation Efficiency Act as amended.

The Problem

The current problem is demand for maintaining the now-aged interstate roadways and building additional interstate roadways to serve areas that have greatly expanded since the initial system was built. Interstate designations have been made by political action; however, strict federal interstate standard requirements must be met before acceptance into the program. Requirements have become even more stringent in the intervening years.

In Texas, major strides have been made to meet needs and expectations.   In the example of the future I-69 in Texas, 160 miles of controlled-access improved roadway are already in place and near interstate standards. The major hurdle for having the interstate shield applied to the upgraded sections is that they are not part of a continual interstate highway.

Congressional actions on designation of the I-69 route have taken place in every surface transportation authorization act since 1991, each time slightly adding or amending language on the routes, but no federal actions provide implementation funding. A recent Texas Department of Transportation (TxDOT) estimate to bring all designated Texas I-69 sections up to full interstate standards – including construction, right-of-way, and engineering – is $6.8 billion (TxDOT 2010).

Is the Shield Necessary for Economic Development?

The I-69 Texas highway is being developed piecemeal as funding becomes available from a variety of sources, including $270 million from the recent American Recovery and Reinvestment Act to make incremental progress on sections of US 59, US 77, US 281, and US 83. But sections that are improved and possibly operating at even higher efficiency than sections of signed interstate do not carry what some economic development specialists believe necessary: the interstate shield.

In today's business environment, how important is that shield? No quantifiable research backs up the claim of its absolute necessity, but transportation access is almost always a factor in the decision-making process. Site-selection consultants use screening criteria to evaluate alternative new-business or relocation sites. The list of criteria varies depending upon the business type. However, all lists include an examination of transportation access.

"…some states build limited access four-lane highways that function like interstates, but often fail to market them sufficiently."

A literature review finds that at least one site-selection firm maintains its own geographic information system (GIS) database of four-lane highways and notes that "some states build limited access four-lane highways that function like interstates, but often fail to market them sufficiently" (Farmer 2009). With today's congestion on urban interstates, site-selection specialists also examine choke points for impact on commuters and look at access to public transportation options.

When the biggest concern in the business location decision is goods movement, not people movement, myriad factors may affect future needs. Some factors are rising fuel costs, a rise in domestic "re-shored" manufacturing (returning to the United

States from abroad), the evolution of mega-regions, and an emerging trend of collaborative logistics where companies attempt to merge networks on a spot or regular basis (Bruns 2011). Kraft, for example, is finding new ways to ship orders directly from plants to top customers, forgoing a distribution center. Generally, e-commerce facilities (such as Amazon) are not as sensitive to distance and location-based differences in freight costs and attempt to locate where they may not be in as much competition for labor with retail-store fulfillment distribution centers.

Regardless of the changes that may be coming, the immediate-future demand in Texas along the future I-69 is substantial. While the initial interstate system was designed to connect cities of 50,000 or more, the population of Hidalgo County alone is now estimated at nearly 750,000, an increase of 30 percent since 2000 (U.S. Department of Agriculture 2011). Even if interim solutions help, the long-term need to build the entire route to higher standards will remain.

Solutions and Benefits

Is it possible to pursue a lower-cost interim solution?

Today the federal and state governments across the country have difficulty identifying additional resources for major roadway expansion, and will be struggling for some time to even maintain the system in place. Taking a different strategic approach may be practical. While agencies should be alert to every available funding opportunity, alternative supplementary approaches deserve consideration. One possible interim solution, prior to full improvement, could be the national introduction of a subclass of interstate highways being proposed by two transportation professionals, Weiss and McCuen. Martin Weis is a retired Federal Highway Administration (FHWA) employee who worked on interstate designation and numbering, and Alan McCuen is a former deputy director of the California Department of Transportation district that includes Fresno.

Their possible solution would be to designate roadways at near-interstate design levels as “interstate connectors” and to

A possible solution could be to designate roadways at near-interstate design levels as "interstate connectors" and allow signing similar to an interstate shield.

Figure 6. Proposed interstate connector signage.

An interstate connector system could likely be implemented by the U.S. secretary of transportation but would probably merit congressional approval.

allow signing similar to an interstate shield. Weiss and McCuen claim that this new signage system could achieve a substantial portion of the objectives of interstate designation at much less cost than improvement to interstate design levels (Weiss and McCuen 2008, Weiss 2009).

They propose that these connectors carry signing similar, but not identical, to an interstate shield. Illustrative examples are provided in Figure 6. Exit numbering could be allowed as if the highway were already a full interstate highway; this would allow for continuity and less confusion to the public. Weiss and McCuen propose the same exit numbering change for all of the roads designated as future interstates. The California example provided in their proposal applies to State Route 99 from Bakersfield to Sacramento, where some sections could – subsequent to ongoing improvement – have full interstate signs, while most sections would have interstate connector signs. Nonetheless, the exit signs could be sequentially numbered.

While the U.S. secretary of transportation already has the authority to designate interstate connectors because no law expressly forbids it, congressional approval may also be warranted because such a designation is a substantial variance from existing policy.

One possible downside of implementing the connector signing scheme is a possible reduction in the rate of freeway improvements to full interstate standard, although the rate is already very low, even before the current poor fiscal condition of the federal transportation trust fund.

Such a proposal would surely require the endorsement of other state departments of transportation and the American Association of State Highway Transportation Officials (AASHTO), in particular its Route Numbering Committee.

Economic Impact of Interstate Highways

While the construction of new interstate highways has been steadily declining, interest continues in evaluating highway

Highways are a "necessary, but not sufficient condition" for generating economic development, at least in rural locations.

investments (as well as other modal investments) as economic development strategies. The literature on the economic effects of highway investment is wide ranging, as shown in an annotated bibliography conducted by the U.S. Department of Agriculture's Economic Research Service (Brown 1999). As noted in the comprehensive bibliography, many studies find that transportation infrastructure is important in generating local economic development and increasing overall employment within the region (FHWA 1996). They conclude that highways are a "necessary, but not sufficient condition" for generating economic development, at least in rural locations. What are those other conditions?

A few general conclusions have surfaced from the studies reviewed by Brown about the potential impact of highway investments on rural economic development.

First, it appears those rural counties in close proximity to metro areas and those with some prior degree of urbanization benefit economically, especially from interstate highways. The highway construction expenditures benefit rural employment in the manufacturing and retail sectors, with effects strongest in the short term. There is little consensus about how the highways affect rural areas over the long term, with some studies arguing that highways merely redistribute development potential from other areas (Brown 1999).

Brown concludes that current data sources are inadequate for measuring economic effects of highway investment, and future efforts should be directed at developing better regional data sources for detecting highway-specific effects, perhaps through the use of GIS applications. One of the challenges mentioned is the difficulty of accurately measuring the economic effects of highway investment as isolated from the larger processes associated with regional economic growth.

FHWA funded research, completed in 2005, on the economic effects of selected rural interstates at the county level. This research focused on the economic development history of completed interstates or long portions of such interstates (for example, I-43 and I-81) with characteristics similar to those designated by Congress (including I-69 and I-73/74) but not built (Weiss 2005). The idea was to provide some perspective to anticipate the effects of the subsequent completion of future interstates of similar natures.

Nine interstate or near-interstate corridors were examined. The researchers correlated data, generally at the county level, on population, employment, income, etc., before, during, and after completion of the interstate. In some counties, the changes were similar to changes in counties without interstate access. In others, changes implied that the influence of the interstate was positive from an economic development standpoint.

Hale County, Texas

Fewer people but more jobs

Between 1969 and 2002:

11 percent population loss but 30 percent employment gain

One of the stretches of interstate studied by FHWA was Hale County in the I-27 corridor. Despite the loss of about 11 percent of its population between 1969 and 2002, the county had a 30 percent increase in employment. The study concluded that the increase was substantially due to the success of three industrial parks near I-27 that attracted agriculture-related manufacturing employers.

In summarizing the results of the research, the implication is that a new interstate may result in little improvement in the economic development picture. Results also imply that counties with already partially successful employment expansion programs will have more successful programs if an interstate is nearby. Other research does conclude that transportation investments can have broad benefits to regional economies. Finally, most of the major studies have concluded that the impact of a given transportation project is difficult to measure. While this may be true, it does not preclude the possibility that economic benefits from designating current highways to interstate or interstate-equivalent corridors could result in substantial long-term economic benefits for Texas.

Perception versus Reality

Even though it does not appear that a sufficient body of research is in place to prove that an interstate highway is necessary for future economic development in either urban or rural areas, this does not diminish the belief of economic development professionals and community leaders that interstate highway availability in an area is needed for economic growth and the long-term vitality of the region.

It is possible that increased communications between and among the economic development community, TxDOT, and other regional and local transportation organizations could be helpful in maintaining reliable data on roadways at near-interstate design performance. Just like the private-sector site-selection firm that maintains its own database of four-lane highways, transportation organizations could develop and maintain a process for providing this sort of information.

Possible Actions/Research Needs

Demand is high for additional miles of interstate or interstate-like highways in Texas and elsewhere in the country. Two positive steps should be considered while also pursuing the eventual construction of those miles.

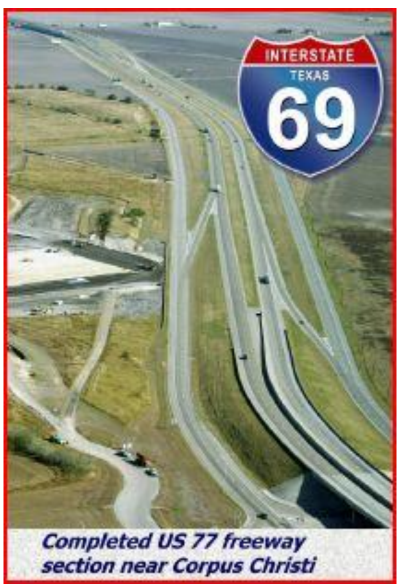

Figure 7. Part of the future I-69, US 77 near Corpus Christi (Alliance for I-69 Texas 2010).

__Enhanced Information for Economic Development__

In real estate, the catch phrase is "location, location, location." But the power of information is also respected. A low-cost, positive action that could be undertaken without any legislative action is the development of simple, clear information on the existing roadways within Texas that are at least at four-lane capacity and clearly provide attractive access.

For example, approximately 160 miles of future I-69 in Texas meet interstate highway standards, except that they are not continuously connected to an existing interstate (Figure 7). Because maps do not identify the roadway with the interstate shield, parties involved in commercial site selection may not be aware of the upgraded roadway. An interdisciplinary task force could consider preparing data and maps to brief and continually update the national site-selection community on improved highways statewide.

TxDOT, working with other roadway developers such as regional mobility authorities or regional tolling authorities, and metropolitan planning organizations could prepare the information on these improvements. Possible other participants in determining the desirable data and format could include the Governor's Office of Economic Development and Tourism, representatives of the economic development community throughout the state, and other interested stakeholders (such as the Alliance for I-69 Texas). It would be prudent to highlight upgrades occurring on four-lane highways in all areas of the state.

Research Needs. It may be necessary to create a new database that accurately reflects and maps the improved roadways. An internal TxDOT working group or researchers could help develop the database. Existing TxDOT databases do not include a category that highlights sections of highway that are at interstate standards except for meeting the interconnectivity requirement; adding this subcategory could be helpful.

Surveying a sample of regional and national economic development specialists to verify the type of information and formatting needed to make it most useful could also be considered.

Pursuit of New Interstate Connector Signage Category

If no substantial transportation funding results from the current debates on federal and state funding, the idea of creating a new category of interstate connector signage might be an attractive interim action. A TxDOT-related champion – possibly a Strategic Research Program Advisory Committee member or someone within the department – or a representative of a major transportation advocacy group would likely be necessary to develop an approach and gain acceptance nationally. Key states that could be prime supporters of the concept include California, Kentucky, New York, Pennsylvania, and Tennessee.

Research Needs. Additional research could be helpful to develop this strategy. To pursue the idea further, the Advisory Committee or TxDOT might wish to receive a briefing by one of the initiators of the idea of interstate connector signage, Martin Weiss. TxDOT staff is already conversant in the federal legislative and administrative requirements related to interstate designations. Assistance might be required to reach out to other states to test interest and gather data on the status of completion of future interstate links elsewhere.

Conclusion

Taking positive steps:

- *Tout existing and near-term improvements*
- *Consider new interstate connector signage*

The interstate routes that pass through Texas today were instrumental in the state's development. They form the major arteries of the state's circulation system, and maintaining them in healthy condition is a top priority. Like the aging population's medical costs, maintenance and rehabilitation are not inexpensive.

While economic development can occur with and without interstate highways, it is not the only rationale justifying expansion and improvement of the interstate system in Texas. The need to make connections with rapidly growing regions is important. The current and future needs to serve international trade and improve safety are as well.

As a research area, the quantification of the economic impact of construction of interstate highways, especially in rural areas, may be the most elusive. However, that does not diminish the popular perception that interstates make positive impacts on economic development. Taking some positive steps to tout the existing and near-term improvements (through a coordinated information-sharing effort) and to examine a way to place greater emphasis on improvements completed or underway (through a new interstate connector signage system) may be worthy of consideration.

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