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16. Abstract This research project was established by TxDOT's Research and Technology Implementation Office to address special studies required by the department's Administration during FY 2010. Six short-term, quick-turnaround tasks were completed and are documented.		
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RTI Special Studies for TxDOT Administration in FY 2010

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Chapter 1. Introduction

1.1 Background

This research project was established by the Texas Department of Transportation's (TxDOT) Research and Technology Implementation Office (RTI) in Fiscal Year 2009 and renewed in FY 2010 to evaluate transportation issues as requested by TxDOT's Administration, and develop findings and/or recommendations. The project was structured as a *rapid response* contract for two reasons:

1) Transportation research needs are sometimes identified in a manner that necessitates a quick response that does not fit into the normal research program planning cycle, and
2) Individual transportation research needs are not always sufficiently large enough to justify funding as a stand-alone research project, despite the fact that the issue may be an important one.

The Center for Transportation Research contracted with RTI to provide rapid response teams when work requests came from TxDOT's Administration. Task teams were assembled based on the technical requirements in each case, and worked independently of other task teams. Each team coordinated directly with the Administration member requesting the study, and submitted a technical memorandum at the conclusion of the task, to provide TxDOT with implementation information in a timely manner. This report combines the various technical memoranda completed in FY 2010 for easy reference, and is a follow-up to Report 0-6581-1, which documented the FY 2009 work.

1.1.1 Innovative Research Project

The traditional TxDOT research program planning cycle requires about a year to plan a research project and at least a year to conduct and report the results. With respect to some transportation issues, this type of program is best suited to addressing large, longer-range issues where an implementation decision can wait for two or more years for the research results. In recent years, the need for quick response to district engineers, TxDOT administration, elected officials, and public concerns has become more pressing, as information regarding ordinances, legislation, revenue forecasting, mobility, traffic control devices, intermodal systems, material performance, safety, and every aspect of transportation has become more critical to decision-making. When these initiatives are initially proposed, TxDOT has a very limited time in which to respond to the concept. While the advantages and disadvantages of a specific initiative may be apparent, there may not be specific data upon which to base the response. Due to the limited available time, such data cannot be developed within the traditional research program planning cycle.

As a result of these factors (smaller scope, shorter service life, lower capital costs, and the typical research program planning cycle), some transportation research needs are not addressed in the traditional research program because they do not justify being addressed in a stand-alone project that addresses only one issue. This research project was developed to address these types of research needs.

This type of research contract is important because it provides TxDOT with capabilities to accomplish the following:

1. Address important issues that are not sufficiently large enough (either funding- or duration-wise) to justify research funding as a stand-alone project.
2. Respond to issues in a timely manner by modifying the research work plan at any time to add or delete activities (subject to standard contract modification procedures).
3. Effectively respond to legislative initiatives.
4. Address numerous issues within the scope of a single project.
5. Address many research needs.
6. Conduct preliminary evaluations of performance issues to determine the need for a full-scale (or stand-alone) research effort.

1.2 Research Tasks

Succeeding the five tasks completed in FY 2009, the following six tasks were completed in the period September 2009 to August 2010:

Task 6: Assessment of TxDOT Project Delivery Business Model and Costs

The objective of this task was to analyze TxDOT's current highway design plan project delivery business model, compare it to "best practice" public sector and private sector design plan project delivery models, and provide recommendations for TxDOT to implement best practices and related efficiencies.

Task 7: Policy Research Project Examining ARRA 2009 Stimulus Money Impacts in Texas

The objective of this task was to support a two-semester Policy Research Project (PRP) at the LBJ School of Public Affairs at The University of Texas at Austin, where upwards of 12 students worked under the supervision of Leigh Boske and Rob Harrison to address different aspects of the American Recovery and Reinvestment Act (ARRA) evaluation.

Task 8: Pavement Condition Predictions based on TxDOT Funding Projections

The objective of this task was to calculate future pavement Condition Scores using the same methodology and assumptions as were used in the 2030 Pavement Needs study, but based on the current projected funding allocations.

Task 9: Identification of Economically Distressed Areas in Texas

The objective of this task was to identify areas (a region, metropolitan area, municipality, smaller area within a larger community, or other geographic area) that would qualify as an economically distressed area (EDA) as defined by the FHWA under the ARRA, and to determine which TxDOT projects were planned for those areas.

Task 10: Dallas District IH 30 Noise Project

The objective of this task was to examine claims of excessive noise on a section of IH 30 in West Dallas through field measurements and resident interviews, and to identify potential mitigation measures including noise wall treatments and porous friction course (PFC) overlays.

Task 11: Statistical Analysis of TxCAP and its Subsystems

The objective of this task was to conduct statistical analyses of the data used by TxDOT to develop Texas Condition Assessment Program (TxCAP) scores, to help in deciding if the difference between two TxCAP scores is a true difference (i.e., statistically significant) or a measurement error.

1.3 Organization of This Report

This chapter presented the background and justification for this research effort, and the research tasks. At the completion of each task the research team submitted a technical memorandum to TxDOT. This report combines the various technical memoranda for easy reference.

Chapters 2–7 present the results of Tasks 6–11 respectively. Conclusions and recommendations are contained within each task report.

Chapter 2. Assessment of TxDOT's Project Delivery Business Model

2.1 Introduction

Task 6: Assessment of TxDOT Project Delivery Business Model and Costs

The objective of this task was to analyze TxDOT's current highway design plan project delivery business model, compare it to "best practice" public sector and private sector design plan project delivery models, and provide recommendations for TxDOT to implement best practices and related efficiencies.

2.2 Results

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Subject: An Assessment of TxDOT's Project Delivery Business Model

2.3 Research Background

2.3.1 Section objectives

This section provides general background information on TxDOT project delivery issues, the research objectives and work plan, and an outline of this chapter.

2.3.2 Background

The Texas Department of Transportation (TxDOT), in cooperation with local and regional officials, is responsible for planning, designing, building, operating, and maintaining the state's transportation system. Project delivery is a key component of TxDOT's operations. Planning and design (called *preliminary engineering* or PE) are major phases of project delivery.

Quality and timely completion of PE are important to TxDOT. To a great extent the department has decentralized PE services to the district level. Each of the 25 TxDOT districts has area offices where the majority of PE work is either developed or supervised. PE activities are spread among 135 locations, including 119 area offices, and metropolitan and urban district headquarters. This report presents an assessment of TxDOT district project delivery practices.

Approximate staff strength of TxDOT is 15,000. Among them, 4,600 employees work on engineering functions (TxDOT Work Force Plan 2009–13). Traditionally, TxDOT performed all preliminary engineering activities in-house. In 1997, the Texas Legislature passed a law requiring that at least 35% of TxDOT's engineering work must be contracted out to consultants. Due to many internal and external factors, consultants now account for a significant portion of TxDOT PE expenditures. For TxDOT projects let in fiscal years (FY) 2006–07, TxDOT spent $471 million on PE, of which about 35% was in-house charges, 5% was distributed indirect costs, and about 60% was consultant charges (Persad & Singh, 2009).

Outsourcing of engineering work is a contentious issue within state departments of transportation (DOT) across the U.S. and the consultant community. In most cases, the debate centers on cost comparisons. However, DOTs outsource because of workload variations, staff shortages, and schedule demands, and the comparative cost of doing the work in-house is not an overriding factor in the decision.

2.3.3 Research objectives

A systematic approach to project delivery that includes optimum involvement of the private sector can enhance the performance of any DOT. In this context, TxDOT's primary need is an assessment of its PE project delivery model, both in-house and through consultants. The assessment should include a review of procedures for determining what types of PE work should be done in-house and what types or how much should be outsourced. Research is required to address the following questions/issues related to this topic:

1. What are the decision criteria used to determine what types of PE work are best performed in-house and what types are candidates for outsourcing?
2. How can outsourcing be best used to complement the department's internal highway design staff strengths to expedite project delivery?
3. How can the department implement potential efficiencies and best practices in PE project delivery?

2.3.4 Research approach

To answer the above questions, a three-pronged approach was used:

1. Synthesize information on DOT and private sector project delivery models and decision tools.
2. Through questionnaires and interviews, document TxDOT procedures, and identify opportunities for improvements.
3. Develop recommendations for implementing best practices.

The research work plan was as follows:

A. Literature Review (September 09)

1. Acquire information on design plan project delivery and outsourcing approaches in the private and public sectors, and identify successful practices.
2. Focus on best practices that could be implemented by TxDOT.

Output: Project delivery and outsourcing techniques/procedures that have proven successful in the private or public sector, and are applicable to TxDOT (Sections 2.4 and 2.5).

B. Analysis of Internal Strengths (October 09)

1. Analyze the types and volumes of design work being done in-house by TxDOT compared to the types and volumes of design work being outsourced.
2. Analyze TxDOT's design plan project delivery procedures through questionnaires and interviews.
3. Identify internal design staff strengths and opportunities to implement best practices.

Output: Internal opportunities to enhance project delivery procedures (Section 2.6).

C. Analysis of Project Business Delivery Models (November 09–February 10)

1. Compare TxDOT's project delivery model with strategies in other DOTs and the private sector.
2. Identify and prioritize factors to be considered in the "make or buy" decision for activities, functions, projects or programs
3. Develop recommendations for implementing best practices in project delivery decision-making.

Deliverable: A report, Executive Summary, and Power Point presentation documenting procedures and recommendations for best practices and decision support systems to improve TxDOT project delivery practices (Sections 2.6 and 2.7).

2.3.5 Chapter structure

The rest of this chapter is organized into four sections. Section 2.4 provides a discussion of trends in project delivery in the private and public sectors. Section 2.5 examines models used by various businesses and public agencies for deciding what work is done in-house and what is outsourced. Section 2.6 presents an analysis of project delivery practices in TxDOT districts. Section 2.7 gives a summary of findings and recommendations for improvements. It includes an outline procedure for selecting work to be done in-house and for outsourcing.

2.4 Project Delivery Trends and Issues

2.4.1 Section objectives

This section describes trends in project delivery in the private and public sectors, based on an extensive literature review. It is seen that more and more industries are outsourcing specific functions. The magnitude, reasons for, and impact of outsourcing are discussed. Issues affecting project delivery decisions are also explored.

2.4.2 Introduction

A growing number of businesses now execute only their core competencies in-house, and hire consultants for specialized work. "Outsourcing" is defined as procuring a service outside the company as an extension of the organization's business, with the provider responsible for its own management. Outsourcing is now a widely utilized practice in the business world, and has become an essential part of project delivery. Essentially, processes that might otherwise be performed by in-house employees are subcontracted to other organizations. Global outsourcing expenditure peaked at $1 trillion (US$) in 2000 according to a Dun & Bradstreet study, with about $318 million of that being from the United States (Chelikani et al.).

Outsourcing is considered a strategic tool to improve performance delivery, and the public sector has begun adopting it. Public sector outsourcing gained visibility when California voters passed Proposition 13 in 1978. Then, in 1981, President Reagan brought in an administration that pressed hard for the increased outsourcing of federal services (Allen et al., 1989). State transportation departments have widely adopted outsourcing as a strategy for project delivery.

2.4.3 State DOT project delivery trends

Historically, in state DOTs most of the engineering and design were done by in-house staff even though contracting out of construction work was the norm. However, states like Minnesota had contracted out pre-design activities as early as in the 1960s. According to a 2007 study by the National Association of State Highway and Transportation Unions (NASHTU), over the past few decades the use of consultant engineers has increased in several DOTs. In 1997, the Texas Legislature passed a law requiring that at least 35% of TxDOT's engineering work must be contracted out to consultants. Currently, consultant involvement in preliminary engineering (PE) and construction engineering (CE) varies across state departments of transportation (DOT). Some DOTs outsource only specific engineering work like geotechnical investigations, while states such as Illinois, Indiana, Iowa, Louisiana, and Rhode Island have privatized almost all of their PE work.

Historical trends—mostly PE activities contracted

Data from 31 states showed that, in 1988, the median construction program was about $350 million and the median expenditure for consultants was $12 million (Appendix A). In 1998, with 28 states reporting, the median values were $400 million and $25 million respectively. Thus, though the median increase in construction volume was about 15%, the median outlay for consultants doubled (NCHRP Synthesis, 1999). A Wisconsin audit report of 1997 found that consultant involvement increased 36% in the period 1987–1997 (NCHRP 277, 2003).

The level of consultant usage by DOTs for PE and CE work in 1998 is given in Appendix B. Most of the states were contracting out more than 50% of their work, with New Jersey at 85%. In the period 1992–2002, NJDOT saw an increase of 2650% in the total cost of outsourced contracts, from $3.9 million to $105.4 million. Not shown in that list is Indiana, which, as of 1998, had privatized virtually the entire PE function, outsourcing 99.8% of its preliminary design work (NASHTU, 2007).

In 2000, the Federal Highway Administration (FHWA) surveyed DOTs regarding outsourcing. The response summary is given in Table 2.1. It shows that most of the states contract out design work. Nevada topped the list, contracting out nearly 100% of design work (NCHRP, 2001).

Table 2.1: State DOT Outsourcing in 2000

State	Work Outsourced	Percent Contracted	Comments
AL	Design & Construction Inspection	Most	
AK	Construction Contract Admin	10%	
	Design	31	
CO	Design and Construction Oversight	51%	
CT	Design	72%	
	Construction Inspection	61%	
DE	Design	60%	
	Construction Inspection	60%	
GA	Design	25%	
ID	Design Construction	67%	
	Management	10%	
IA	Construction Inspection	25%	ROW 0%
	Roadway Design	62%	
	Bridge Design	41%	
	Planning (Location & Environmental)	18%	
KS	Design	70%	Maintenance In-house
KY	Professional Services Construction Services	80% 5%	Design, Environmental Studies, Planning, Underwater Bridge Inspections, Photogrammetry
ME	Highway Design	30%	
	Bridge Design	20%	
	Construction Engineering	13%	
MD	Plats, Surveys,	90%, 33%,	
	Mapping, Design	100%, 60%	
MO	Highway Design	82%	Construction Inspection 0%
	Bridge Design	16%	
NE	Design	35%	Construction Inspection 0%
NV	Design	99+%	

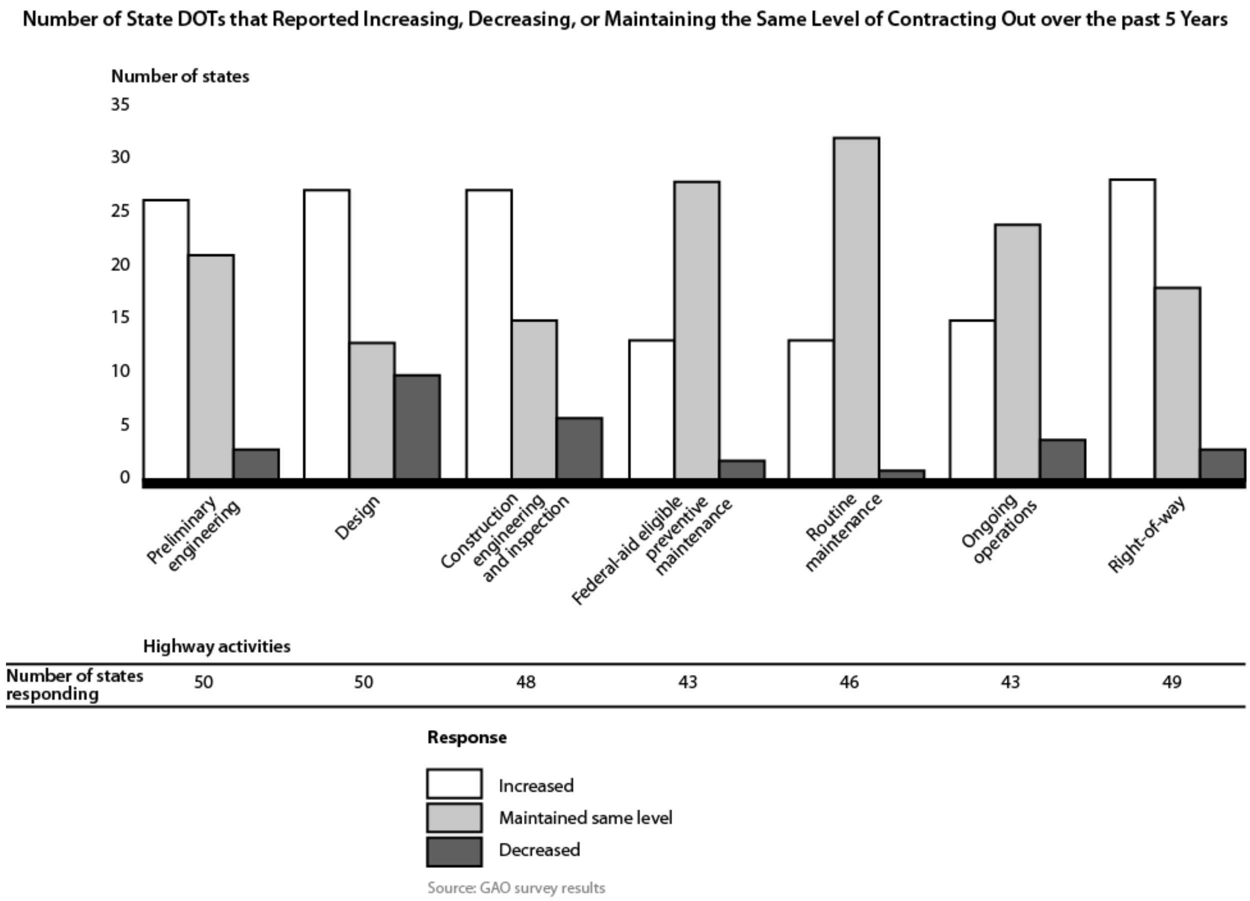
State	Work Outsourced	Percent Contracted	Comments
NH	Design	33%	
NJ	Design	95%	
	Construction	30%	
NM	Design Services	40%	Pavement marking 100%, Signing 100%, Logo 100%, CM services
ND	Construction Engineering Services	20%	
	Design	50%	
OK	Design	70%	
	Construction Inspection	10%	
	Bridge Inspection	75%	
PR	Engineering Services	90%	
TN	Design	50%	
	Construction Inspection	100%	
	ROW Appraisals	60%	
	Environmental Studies	60%	
TX	Preliminary Engineering Services	51%	
	Design Construction Services	2%	
UT	Design	45%	Construction Inspections
WA	Design & Construction Services	Most	EIS, Design & Construction Inspections
WV	Preliminary Engineering Services	75%	Environmental Documents, Plans, Construction & Bridge Inspections, Materials Inspection & ROW

Source: NCHRP, 2001

In the Florida DOT (FDOT) in 2001, consultants performed 76% of design work, including project development and environmental studies, and all aspects of design and post-design services such as shop drawing review. In addition most FLDOT districts have General Engineering Consultants who perform the DOT's role in managing and reviewing other consultant's work. The outsourcing figure for FLDOT in 2008 was 81%, and it is projected to grow to 84% in FLDOT plans for fiscal years 2009–2013 (FLDOT, 2008).

Recent trends—more CE activities contracted

There is an increasing trend for DOTs to contract out construction engineering work. In 2006, the United States General Accounting Office (GAO) conducted a survey among states regarding the volume of outsourcing in state DOTs. The survey included PE activities (surveying and mapping, locations studies, traffic studies, planning, and environmental impact analysis), design (preliminary and final design work), and CE and inspection (inspections, materials testing, construction management, and schedule analysis). The study found that over the previous 5 years, more than half the states increased the amount of PE, design, and right-of-way activities as well as CE and inspection activities contracted out to third parties. A smaller number of states increased their contracting of maintenance and operations activities (GAO, 2006). Figure 2.1 shows the DOT trend in outsourcing over the period 2001–2006.

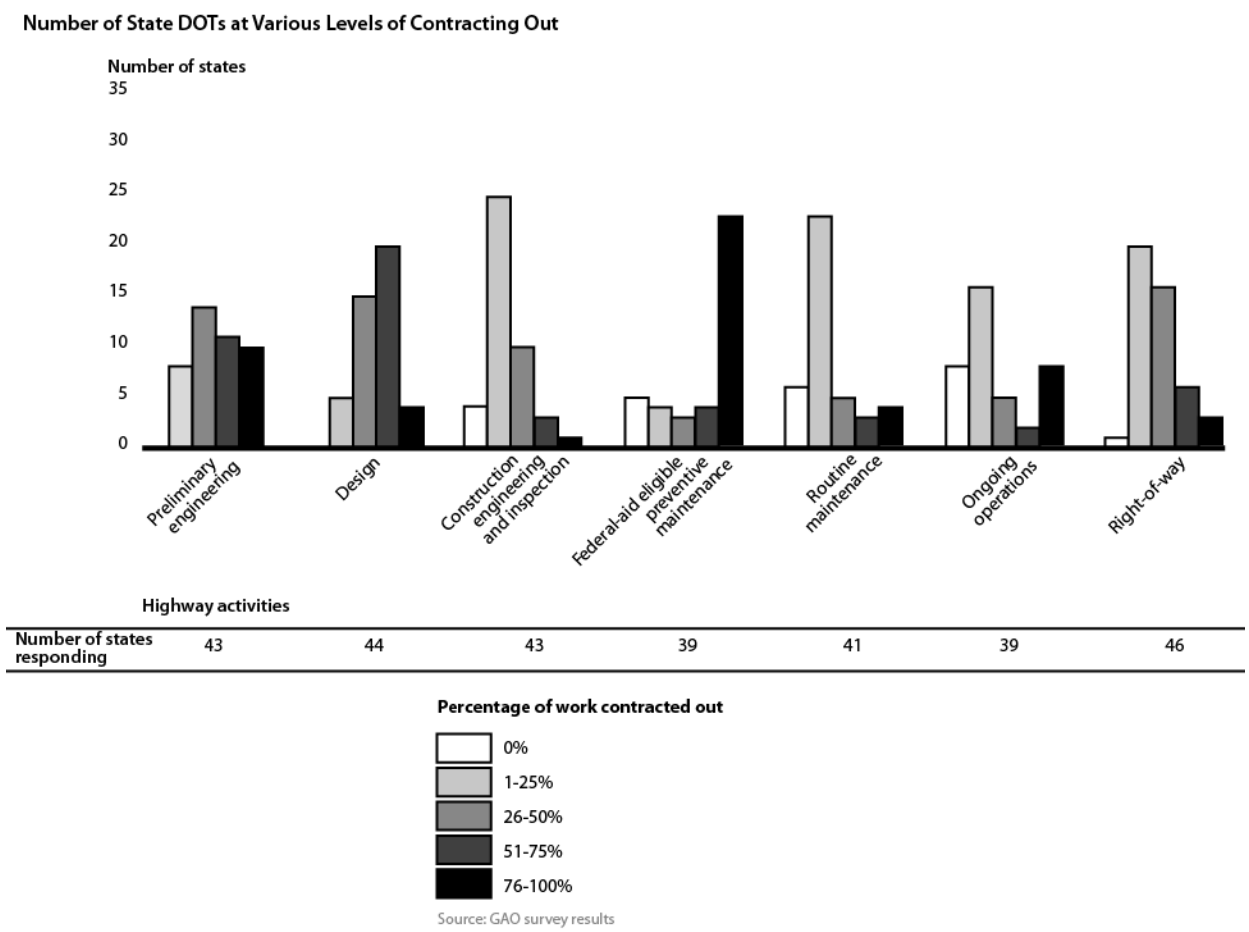


Source: GAO, 2006

Figure 2.1: Outsourcing Trends 2001–2006

In the GAO report, officials from 27 of the 50 states indicated that their states had increased the contracting out of CE and inspection activities, although half the states reported contracting out 25% or less of this work. Several states indicated that they have recently had to increase their use of consultants for construction inspection activities. For example, the South Carolina DOT (SCDOT) began to increase its use of consultants to perform CE and inspection work in 2000, estimating that they will contract out about 10% of those activities. Prior to 2000, the SCDOT only contracted out construction inspection and engineering work on certain large, complex projects. Maryland State Highway Administration officials also said that they have been hiring consultants for what have been traditionally in-house construction engineering and inspection activities, contracting out about 60% of these activities (GAO, 2006).

Figure 2.2 shows the amount of different types of work outsourced by various DOTs as of 2006. Officials from at least three state DOTs reveal that they would prefer to keep CE activities in-house to retain greater control over the quality of contracted work. For example, Illinois highway department officials said that they always assign an Illinois highway department engineer to oversee the consultant because they do not like to have consultants oversee other contractors and consultants, but that they need to contract out inspection activity for projects that require expertise they do not have in-house. The Maryland State Highway Administration officials also said that they would prefer to retain the construction engineering and inspection activities in-house, but they have been unable to hire a sufficient number of staff. According to Utah DOT officials, the agency has been able to avoid contracting out any CE and inspection activities so far, but they would likely contract out such activities in the future if workload burdens on in-house highway department staff continue to increase (GAO, 2006).



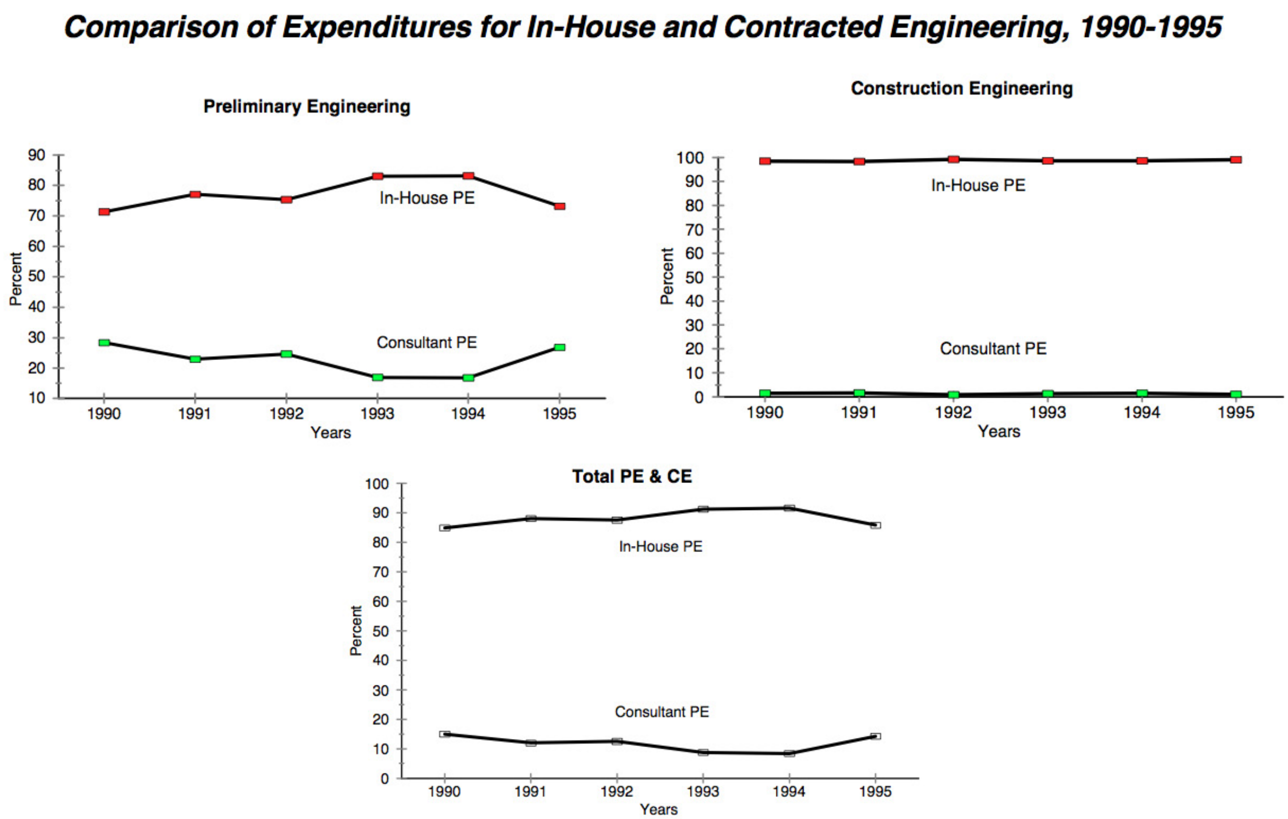
Source: GAO, 2006

Figure 2.2: Amount of Different Kinds of Work Outsourced by Various DOTs as of 2006

TxDOT project delivery trends

Texas has a total of 190,570 lane miles of highway, the largest number of all U.S. states. In 2007, TxDOT ranked highest in highway funding, but second in Full Time Equivalents (FTE) staff. A study by Deloitte in 2007 found that TxDOT faces a workforce shortage. The department could lose a significant portion of its institutional knowledge in a few years when about 70% of managers and about 27% of all current employees will be eligible for retirement. Limited department career paths due to a mandated 11:1 supervisor/employee ratio, and an expanding private market with higher salaries, are also factors in workforce loss (Deloitte, 2007).

Overall, in 1990, 15% of TxDOT's engineering expenditures were for outside consultants. In 1991, the Legislature required TxDOT to achieve a balance between the use of department employees and private contractors for PE and CE (Sunset, 1996). In 1995, 26.8% of the agency's PE expenditures were for outside engineers, but only 1% of expenditures for CE were for outside consultants (Sunset, 1996). Figure 2.3 shows TxDOT PE and CE outsourcing during 1990–1995.



Source: Sunset Report, 1996

Figure 2.3: TxDOT Outsourcing During 1990–1995

From 1994 through 1999, TxDOT's contracts to private firms for PE went from $15 million to $123 million, an increase of 720%, pushed by the 1997 law requiring that at least 35%

of TxDOT's engineering work must be contracted out to consultants. By 2007, approximately 60% (based on recorded PE and CE expenditures) of TxDOT's entire project development process, including design, was performed by outside consultants. This growth was fueled by the large and increasing size of the construction and maintenance programs, and TxDOT's lack of internal capacity to perform all of the design work required.

TxDOT generally does not hire third parties to augment the inspection function, even though the inspection resources in some districts are stretched to capacity. "TxDOT considers the construction inspection function to be representative of its commitment to quality to the Texas traveling public and therefore generally uses inspectors that are Full Time Equivalents (FTEs) of the organization to perform the primary evaluations of its projects" (Deloitte, 2007). The situation is changing, with TxDOT's decision to outsource certain inspection activities such as material testing to help ease the workload of inspectors.

However, this trend toward outsourcing more work has placed an increasing load on TxDOT to effectively manage and monitor the large volume of external consultant work. It would require TxDOT to establish standards of risk, quality, and practices to ensure the consultants deliver services consistent with the organization's current business practices. TxDOT work force needs to be trained in managing and overseeing consultant work such as monitoring work progress, evaluating invoice payments, coordinating work tasks and ensuring compliance (Deloitte, 2007).

2.4.4 State DOT staffing and workload trends

Staff shortages and increasing construction volume are two forces driving DOTs to engage more consultants.

DOT staffing trends

As the construction volume of DOTs has increased over the years, consultants have played a larger role in supporting DOT staff (Appendices A and B). The change in staff strength in various skills in DOTs over 2001–2006 is shown in Table 2.2 (GAO, 2006). Of the 50 DOTs that completed the survey, only 12 stated that they employ more professional and technical highway staff than they did in the previous 5 years. The remainder said that their workforces have either stayed the same or decreased over the last 5 years. There is a concern among states regarding core competencies because too much outsourcing could lead to an irreversible decline in the project delivery skill sets of in-house staff.

The Arizona DOT uses private consultants for 5% of dollar value of their program and sometimes hires back their own retired personnel, which is 30–49% more expensive. They also hire interns for peak summer construction season. Due to work force reduction in 1991 and 1995, the Virginia DOT (VDOT) employs more consultants, and now 30% to 40% of VDOT's inspection force consists of consultant inspectors. Wyoming DOT reveals that in certain cases, inspection by consultants caused more work (AASHTO, 2007).

Table 2.2: Number of State DOTs Reporting Changes in Professional Staff over 2001–2006

Type of professional and technical staff	Increased	Decreased	Stayed the same	No basis to judge
Planning and environment	16	13	18	1
Design (roadway, bridges, and traffic engineering)	4	28	17	0
Construction engineering and inspections (inspections, materials testing, and scheduling)	9	20	20	0
Operations (ongoing Intelligent Transportation Systems, toll collection, and signal and sign systems)	11	8	23	6
Maintenance	6	20	20	1
Right-of-way and utilities	7	15	24	2
Other non-administrative	2	10	23	12
Overall professional and technical staff	12	21		

Source: GAO, 2006

Colorado DOT began using private engineering firms to assist and supplement its contract administration and field engineering work force in 1984–86. Today, all six Engineering Regions are using a concept where non-project specific contracts are awarded to one or more firms in each region and when the need arises for help on a specific project, an order is cut from the master contract assigning the private firm to that project. The scope of work today generally includes a provision for the state's engineer to include people provided by the private firm capable of performing construction inspection services (AASHTO, 2007).

In Kansas, 30% of the construction inspection is done by consultants to the Kansas DOT (KDOT). In some cases entire projects are inspected by consultants and on others they are used to supplement KDOT personnel. Michigan DOT started using consultants in 1996 to supplement staffing and currently have from 8 to 10 projects either completed or underway with 2 consultants (AASHTO, 2007).

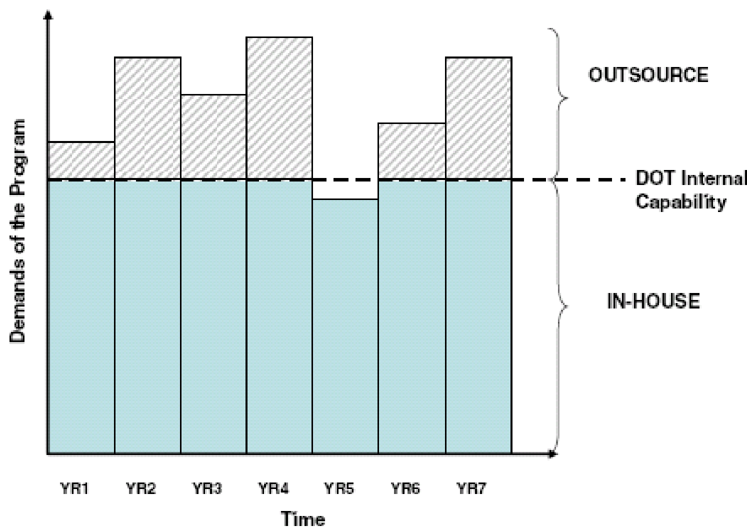
Georgia has found an innovative solution, Rent-A-Tech. In this program, consultant inspectors are assigned to department project engineers within defined geographic areas based on workload demands of various projects within the area. New Mexico's "on call" construction management services utilize contract inspectors to fill in during peak times and sent home when not needed (AASHTO, 2007).

DOT workload trends

State DOTs experience funding fluctuations from year to year, making workload predictions somewhat uncertain. For example, Appendix A gives the changes in DOT construction funding in the period 1988–1998. The Transportation Equity Act for the 21st

Century (TEA-21) of 1995 provided states with a funding increase of more than 44% in their federal programs, from $20 billion to nearly $30 billion. DOTs could not quickly recruit and train staff for the increased workload. There was also a concern that this was a temporary funding increase, so hiring permanent staff was not feasible. A similar situation was experienced with the American Recovery and Reinvestment Act of 2009 ("The Obama Stimulus Program").

Figure 2.4 is an illustration of hypothetical project volume fluctuations in a DOT and the need for outsourcing extra work (peak shedding). Note, however, that the dotted line between in-house and outsource ("DOT internal capability") suggests that there may be periods when in-house staff may be under-utilized. The level of in-house versus outsourcing is a difficult problem, compounded by many uncertainties.



Source: Hallowell et al., 2006

Figure 2.4: Workload Fluctuations in a State DOT

2.4.5 Factors influencing outsourcing

Apart from staff shortages and fluctuating workload, an NCHRP study in 1999 identified two additional factors that influence outsourcing, namely, the need for special skills, and legal/policy mandates. That study concluded that staff shortage is the biggest reason for outsourcing (NCHRP, 1999). Table 2.3 shows the results of that assessment. It lists the number of states that ranked each factor as of high, medium, or low importance in the amount of their work done by consultants.

Table 2.3: Importance of factors affecting consultant usage

Factors	High	Medium	Low
Staff shortage	19*	6	7
Peak Shedding	17	7	8
Special skills	6	11	15
Legal and policy	5	2	25

* Number of state DOTs giving that ranking to that factor

Source: NCHRP, 1999

Seven outsourcing factors and their ranking

The GAO study referred to earlier found seven factors that influence recent trends in outsourcing (GAO, 2006):

- Loss of in-house staff: Most of the DOTs have experienced a shortage of skilled staff due to retirement and attrition of employees. Hiring and wage freezes have affected employee morale and hurt recruiting. Moreover, it is very common for in-house engineers to join consultant organizations after gaining their professional license through DOT training.
- Variations in workload: Louisiana DOT officials have noted that added flexibility from using consultants helps them to respond more quickly to spikes in work volume than if they had to bring new in-house staff on board. Once the work slows, it is easy to draw down the workforce without laying-off staff. In Indiana, when the I-69 project was cancelled, the project team consisting of private sector employees was re-deployed on other projects. If the team had been made up of in-house staff, the DOT would have struggled to find suitable work for them (Warne et al., 2008).
- Specialized skills and equipment: In certain skill areas consultants have expertise that is not available in-house. In-house personnel are familiar with typical projects but may need consultant help on specialized work. Preconstruction engineering now includes archeological or environmental studies, or may require complex or unique structural designs. Limited frequency of these projects may not warrant keeping the relevant skills in-house. According to Council of State Governments (CSG) data, more than 32% of state agencies reveal that lack of state personnel and expertise was an important reason for outsourcing (Moore et al., 2000).
- Schedule constraints: Consultants may be able to "load up" a project and execute it very quickly, whereas in-house staff juggling a large number of projects on a "first-in first-out" basis generally cannot. When speed is required, consultants are the preferred choice. The "27 in 7" program of South Carolina DOT started in 1999 is a good example. That seven-year program delivered projects that would have taken 27 years otherwise (SCDOT, 2008).
- Legal and policy requirements: In some states legal restrictions prevent the expansion of the state work force. Some states, like Illinois, Michigan, New Hampshire, and Texas, are required to outsource a certain fraction of their work. For example, the South Carolina Legislature enacted a budget provision in 1996, encouraging the DOT to use the private sector for certain work, like bridge replacements, surface treatments, thermo-plastic striping, traffic signals, fencing, and guardrails, whenever possible. Similarly, Alaska DOT has to involve consultants in PE work due to state requirements. On the contrary, some states may have legislative limitations on their ability to contract out work. For instance, the California DOT, until recently, was in such a situation because of limited authority to contract out engineering services under the California constitution (GAO report, 2006).
- Innovations: The private sector is better at innovating, for a number of reasons including less stringent rules than the public sector on equipment replacement and

authority to use experimental techniques. When untested or unique work is required, consultants are a good choice.

- Cost savings: It is uneconomical for state DOTs to maintain a workforce large enough for peak workload conditions. Instead, work beyond some volume can be more cost-effectively done by consultants.

The GAO study asked states to rank the importance of each of these seven factors in their decision to contract out specific activities. Details of the survey results are given Table 2.4. It is seen that, of the seven factors, lack of staff ranked highest and cost savings ranked lowest in the outsourcing decision.

Table 2.4: Number of State DOTs That Reported Factors as "Important" or "Very Important" in Decisions to Contract Out Activities

Factor	**Preliminary engineering**	**Design**	**Construction engineering and inspection**	**Federal-aid eligible preventive maintenance**	**Routine maintenance**	**Ongoing operations**	**Right-of-way activities**
Lack of in-house staff	45	44	39	34	35	31	44
To maintain flexibility or manage variations in department workload	36	36	32	19	25	17	38
To access specialized skills or equipment	31	30	19	27	23	25	26
To increase speed of completion or to meet specific time frames	35	32	12	21	19	14	39
To meet federal or state legislative mandates, legal requirements, or policy initiatives	20	18	20	17	9	13	15
To identify innovative approaches or new techniques	10	14	4	11	4	11	5
To obtain cost savings	3	3	1	10	9	3	3

Source: GAO, 2006

Issues in outsourcing

There are many benefits to DOT outsourcing, including innovation and the ability to ramp up and down quickly without having to recruit and train extra staff. However, there are a number of issues that need to be considered as part of outsourcing decision-making:

1. Rules: DOT rules for state oversight of highway construction stipulates that "Although the state may employ a consultant to provide construction engineering

services, such as inspection or survey work on a project, the state shall provide a full-time employed state engineer to be in responsible charge of the project" (GAO report, 2006). Thus state employees are considered necessary for oversight of consultants.

2. Competency: In order to manage their massive construction programs, DOTs need to train and groom a minimum cadre of executives and resource staff. DOT managers typically have gone through a progression of experience in design, construction, staff supervision, and project and program management, to move up to executive level. It would be difficult to recruit experts from the private sector for such positions. DOTs therefore need to retain some portion of PE and CE work in-house to provide training. Otherwise, DOTs may lose the skills and expertise to conduct core functions in-house and to effectively negotiate, check, evaluate, or approve the work of external sources.

3. Balance: Outsourcing is a convenient option for DOTs. But the difficulty is deciding what and how much to outsource, and what to handle in-house. Though there is no firm threshold among the states regarding the optimum level of outsourcing, there seems to be some consensus around the 50% range unless there is insufficient state staff to maintain it at that level and still deliver the program (Caltrans, 2008). Dean Carlson, formerly secretary of the Kansas DOT and executive director of FHWA, suggested that the optimum percentage of outsourced work is 50–60%. However, there is no evidence that this target is reasonable, nor is there any agreement over what it means. Is it 50% of the total construction volume, or is it 50% of total PE expenditures?

4. Cost: In the absence of objective criteria for selecting activities or projects to be outsourced, the debate has gravitated to whether in-house or consultant is less costly-even though cost is ranked by DOTs as the lowest consideration in the outsourcing decision. Most studies have concluded that consultants are more expensive than in-house. At least 17 studies over the past two decades have compared the costs of conducting pre-construction engineering design by in-house staff or private consultants, and more than 80% of these reports found that regular public employees are less expensive than private contractors, with the difference in costs ranging from 30% to 100% (NASHTU, 2007).

5. Quality: Like cost effectiveness, quality of consultant engineering services is also a controversial issue. Some studies done by state DOTs like Alaska, Montana, and Wisconsin have concluded that there is no considerable difference in the quality of in-house and outsourced work (Alaska Legislative audit, 1994). The counter arguments are much stronger and provide evidence that shows that the quality of outsourced services is a concern. Los Angeles' Red Line subway is a case study of the hazards of outsourcing an entire project. Areas of thin concrete, air pockets, and missing reinforcing steel in the tunnel walls was found during quality inspection. The "Big Dig," an eight-lane underground highway that runs through downtown Boston and replaced an old elevated highway in 2006, is often cited as an example of the pitfalls of relying on consultants. The Big Dig grew into the most expensive public works project in American history because of poor oversight. Allegedly due to design errors,

five three-ton ceiling tiles collapsed, and later the tunnel developed hundreds of leaks in its walls and roof areas (NASHTU, 2007).

6. Schedule: The argument that the public sector is less expensive and should therefore perform all activities loses its validity if state forces are unable to perform the work for some period because of workload constraints (Griffis et al., 2008). When projects are delayed, additional costs are incurred. There can be an inflation increase in construction costs and a relative increase in design costs as well. In addition, delay in project completion costs the public in terms of delayed benefits. Together, these costs are larger than the small incremental increases that might be incurred by using outsourced engineering and design. A good example of this would be the Mountain View Corridor (MVC) in Salt Lake County, Utah. The estimated cost of this project was $2 billion and the Utah DOT was faced with inflation levels that have exceeded 10% in recent years. For every year that this project is not built, the price goes up approximately $200 million. Because the in-house staff is not enough to perform the engineering, Utah DOT decided to seek consultant help (Caltrans Report, 2008).

Each DOT must decide how much it can utilize outsourcing in its project delivery process to attain a good return on investment and still provide excellent service to the public. It is clear that many factors influence the decision to outsource.

2.4.6 Section summary

This section showed that outsourcing is a growing phenomenon in project delivery, and consultants now play a critical role in most organizations. TxDOT and other DOTs outsource a significant amount of engineering services.

Loss of in-house staff, variations in workload, schedule constraints, legal and policy requirements, need for specialized skills and equipment, innovations, and cost savings are the main reasons behind the outsourcing trend. Among them, cost savings are considered the least influential in the outsourcing decision. Rules, internal competency, work balance, cost, quality, and schedule are all important considerations when outsourcing.

Because outsourcing has become an essential tool for project delivery, the key issue is how to effectively utilize it. In the next section, project delivery models adopted by the private sector and various DOTs are presented.

2.5 Project Delivery Models

2.5.1 Chapter objectives

This section provides a review of the project delivery models used by various business sectors. Examples from the private and public sector are included. Outsourcing decision making methods developed by various DOTs are also discussed.

2.5.2 Overview of project delivery frameworks

Cost effectiveness has always been an influential factor in business decisions. In the 1990s, cost imperatives drove the private sector to adopt outsourcing as a service delivery strategy. Apart from productivity improvement and economic concerns, external contracting spurs innovation, change, and technical expertise (Ashford et al.). In addition, specialization has spawned an active and efficient services sector. Moreover, outsourcing non-core activities enables organizations to focus on key business areas. However, the drivers of outsourcing in the public sector are somewhat different from those in the private sector. In the private sector cost effectiveness has prime importance, whereas the public sector aims at maximizing service delivery.

Unfortunately, most of the time, organizations treat outsourcing as a de facto solution and seldom evaluate the true strategic rationale for pursuing it. Outsourcing brings in significant structural changes only if there is a cohesive master plan, i.e., a strategic outsourcing plan (Boguslauskas and Kvedaravičienė, 2008). An alarming issue is that outsourcing decisions are made with insufficient data to build a business case, decisions being driven by assumptions rather than facts. Research conducted by Lonsdale and Cox (1997) found that outsourcing decisions are rarely taken within a thoroughly strategic perspective, with many firms adopting a short-term perspective and being motivated primarily by the search for short-term cost reductions.

It is a reality that several organizations fail to achieve the intended benefits of outsourcing. For example, a survey carried out by PA Consulting Group (1996) found that only 5% of companies surveyed had achieved high levels of benefits from outsourcing. Because outsourcing decisions can affect the flexibility, customer service and the core competencies of the organization, the success of outsourcing decisions relies on proper analysis of the business situation (McIvor, 2000).

Compared to the public sector, the private sector is more business oriented and hence they assess outsourcing situations in a structured way. Countless management systems and practices have been imported over the years from the private sector into government to make everything "businesslike." Therefore it is worthwhile to consider private sector outsourcing models.

2.5.3 Private sector project delivery models

Outsourcing in the private sector is a strategic project delivery choice giving sufficient attention to economics. The benefits are increasingly associated not only with simple cost-cutting strategies, but also with the following value-adding considerations:

- Access to external know-how
- Technology and innovative capabilities
- Optimization and restructuring of business processes
- Organizational and production flexibility (Ponmariov et al., 2008).

Because the project delivery strategy is streamlined with corporate strategy, the private sector has a well-defined framework regarding staffing their work activities. Generally the following major steps are integral to any strategy:

1. <u>Knowledge</u>: This part tries to understand the general trends prevailing in the market environment, industry, and the company.

2. <u>Planning</u>: Planning decides the future of any strategy. Major activities in this step are analysis of outsourcing goals and reconciling with business direction, setting the

strategy to establish reasons for outsourcing and what value is expected to be received and determining the best business model.

3. Sourcing: deciding on vendors and locations and negotiating the outsourcing contract that specifies the general, financial, and legal framework of the environment.

4. Execution: managing the transition and knowledge transfer, communicating the right message, prioritizing relationship management to make link between vendor and company friction free, implementing nonstop service quality measurements and audits to show that customer needs are being met and steady progress in terms of quality is being made (Boguslauskas and Kvedaravičienė, 2008).

Because planning is the key step in the staffing strategy, it has to be done diligently. Numerous models are used to assess the outsourcing potential of functions. Essential steps in an outsourcing model are:

Stage 1: Define the core activities of the business

Core activities are the functions central to successfully serving the potential customers. Extreme care is needed to distinguish between core and no-core activities. Usually it is done by top management using techniques like decision analysis or decision conferencing techniques.

Stage 2: Evaluate the relevant value chain activities

This step analyzes the competencies of the company in the core activities in relation to potential external sources. Selected core activities are benchmarked against the capabilities of all potential external providers of that activity to enable the company to identify its relative performance for each core activity along a number of selected measures.

Stage 3: Analyze the total cost of core activities

This stage measures all the actual and potential costs involved in sourcing the activity internally or externally. All costs associated with the acquisition of the activity throughout the entire supply chain are considered—for example, costs right from idea conception, as in collaborating with a supplier in the design phase of the component, through to any costs such as warranty claims associated with the component once the completed product is being used by the final customer. The main concern of this stage is identification of all the activities and costs associated with the outsourcing decision (McIvor, 2000). Usually two types of costs are identified: (1) cost estimation for carrying out the activity in-house, and (2) cost estimations associated with potential suppliers identified from Stage 2.

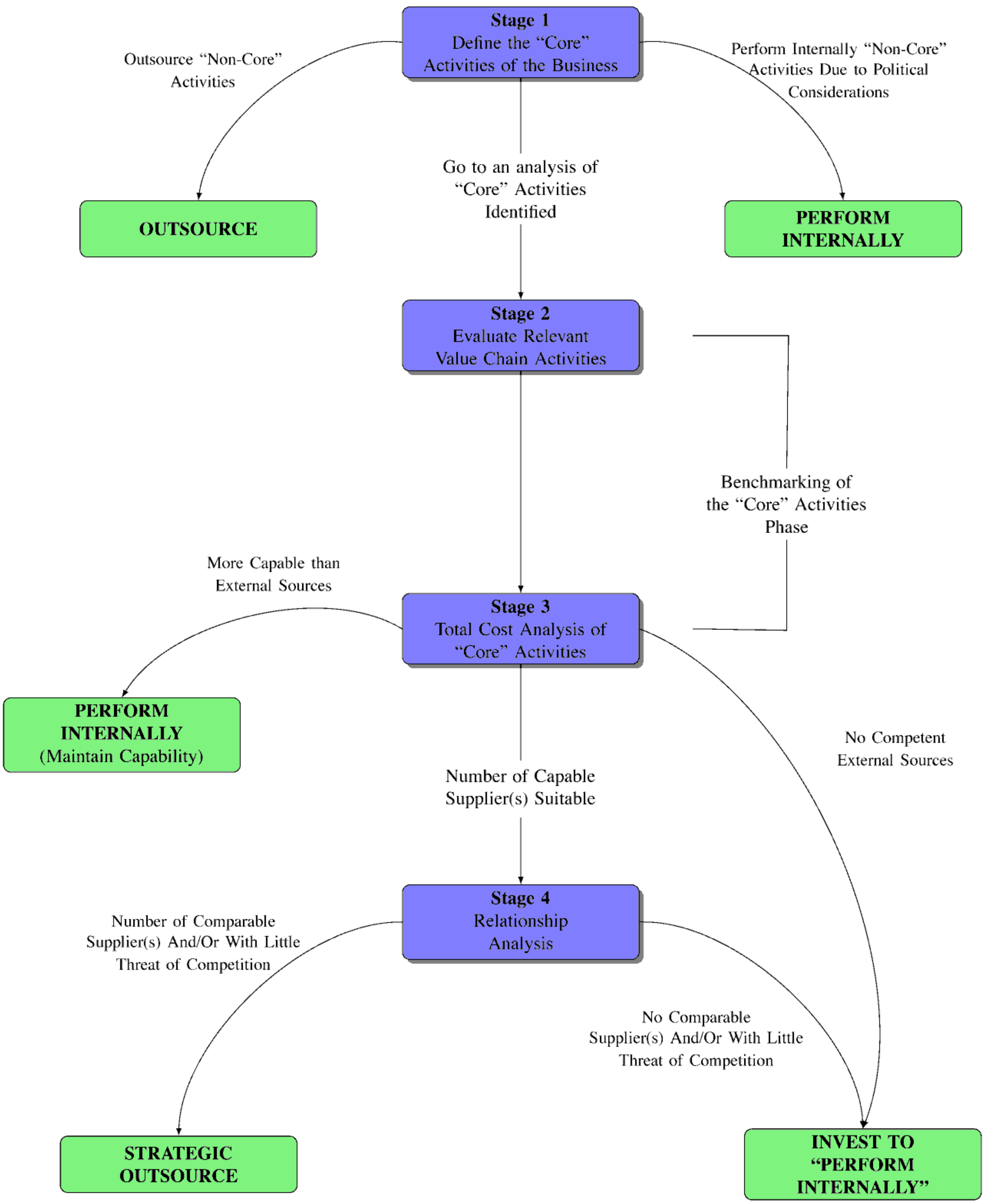
Stage 4: Analyze relationships

Outsourcing a core activity requires serious forethought. Organizations may keep certain knowledge in-house (design skills, management skills, manufacturing, etc.) that enable the technology of the activity to be exploited, even when it is being provided by another partner. Sometimes it is useful to establish a partnership relationship or strategic alliance with a supplier in order to exploit their capabilities, calling for an intensive collaborative working relationship with the prospective partner. NEC's strategic partnerships with companies like Honeywell and Bull helped them to gain more by pursuing a relationship where it holds the balance of power rather than by pursuing a relationship based on equality between partners and the mutual sharing of benefits. Relationships of organizations involved in high technology industries, such as telecommunications and electronics with their key suppliers usually last as long as the suppliers maintained their leadership in technology and quality (McIvor, 2000). Figure 2.5 explains the decision making procedure.

U.S. Shipbuilding Industry

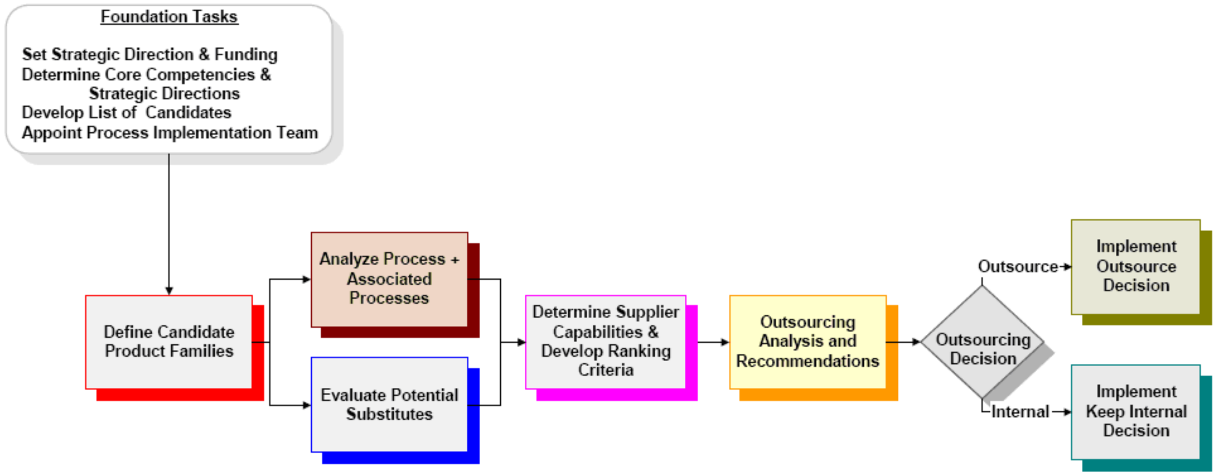
The Strategic Outsourcing Decision Guidebook prepared by NSRP (National Shipbuilding Research Program) and Altarum Institute provides a template for an analytically oriented outsourcing decision process and a detailed description of various factors influencing the decision. Emotional issues of in-house employees, uncertainty, and reluctance to accept the change are the common factors that put decision makers in a dilemma. Lack of sufficient information further intensifies the problems.

Pilot studies of the model were conducted in Northrop Grumman Newport News where they did motor overhaul work internally, fearing loss of skills. A second study focused on the manufacture of low-voltage electrical switchboards and panels at a shop being considered for closure. The entire decision making process is divided into series of steps as shown in Figure 2.6.



Source: (McIvor, 2000)

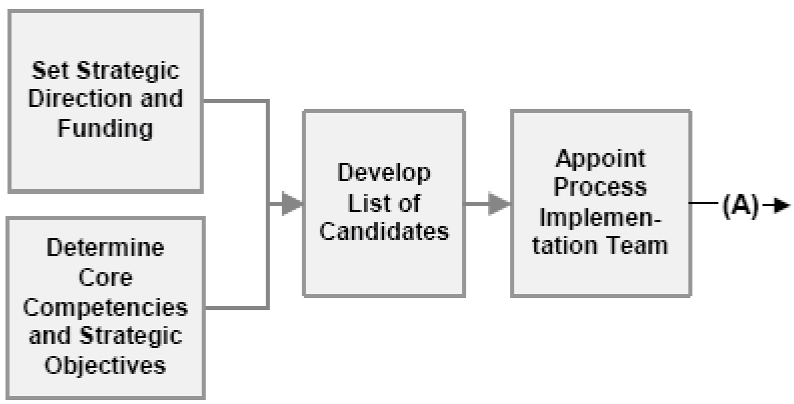
Figure 2.5: Practical framework for evaluating the outsourcing decision



Source: NSRP Strategic Outsourcing Decision Guidebook, 2002

Figure 2.6: Decision making process diagram

Undertaking an outsourcing decision process requires considerable effort and some foundation tasks are needed to be done by outsourcing steering committee. That process is given in Figure 2.7.



Source: NSRP Strategic Outsourcing Decision Guidebook, 2002

Figure 2.7: Foundation tasks preceding application of the decision making process

Foundation tasks precede the formal outsourcing decision making process because the decisions have long term impact on the gearing of the organization. It involves the following:

1. <u>Set Strategic Direction and Funding</u>: Decisions of a strategic nature are to be conducted within the organization's strategic framework. Tactical outsourcing decisions (e.g., due to short term capacity problems) should be within the context of the organization's strategic goals. It is the responsibility of the top management to set the strategic direction and provide the funding required to properly undertake the outsourcing decision process. They are also responsible for allocating human

resources. The Outsourcing Steering Committee has to develop the candidate list and oversee the overall outsourcing decision making process.

2. Determine Core Competencies and Strategic Objectives: Decisions without considering the core competency of the organization is risky because that defines the organization.
3. Develop List of Candidates for Consideration: Functions to be considered for evaluating outsourcing potential are identified in this phase through techniques like brain storming. Later they are prioritized based on the likelihood of success and long term benefit by the judgment committee.
4. Appoint Process Implementation Team: Outsourcing Steering Committee selects the people who will execute the outsourcing decision process, the Process Implementation Team (PIT). The PIT is a team of qualified personnel, including core representatives from purchasing, engineering, manufacturing, planning, and finance. This team will perform the item-specific outsourcing analysis and report results to the Outsourcing Steering Committee that will actually making and implementing the decision. They are also in charge of training new team members and make recommendations for improvement to the process.

In the actual decision making process, the crucial stage is the point at which outsourcing analysis and recommendations are made. Prediction of the likely program impact and final cost analysis are done in this phase. A matrix containing the responsibilities and various roles is given as Appendix C.

An outsourcing decision analysis assesses the costs and benefits of having work performed by internal shops versus outside suppliers. There are two forms these outsourcing decisions can take:

- Strategic Outsourcing, where the shipyard decides whether it wants to make or outsource a type of commodity, and
- Tactical Outsourcing, where the shipyard decides whether it wants to make or outsource a specific part or assembly for an individual ship or series of ships.

The model identifies three factors that should be used as the basis for outsourcing decisions, namely:

1. Strategic concerns for core competence and employee and community relations
2. Lowest total cost (or best value)
3. Impact on operations (NSRP Strategic Outsourcing Decision Guidebook, 2002).

2.5.4 Outsourcing decision making models developed by state DOTs

Numerous studies have been done in the area of outsourcing in state DOTs, and some outsourcing decision making models have been developed. They are discussed below.

Arizona: Quantitative and qualitative models

In this model, the functions for outsourcing are selected based on a qualitative judgment. Initial list is prepared based on the presence of any of five target functions given below.

1. Not central to the agency mission
2. Private sector provider interest exists
3. High level of customer dissatisfaction
4. History of successful privatization by other government entities
5. Cost and/or quality problems

Qualitative analysis is done for the functions included in the initial list. The following factors that could affect the agency's ability to outsource are ranked in this analysis.

1. Strength of competitive market
2. Quality of service
3. Control
4. Risks of contracting out
5. Legal barriers
6. Political resistance
7. Impact on public employees

A profile summary matrix is also prepared that shows the weights assigned to each factor. The evaluator provides two types of numerical scores for the competition of the assessment.

After considering the qualitative questions associated with each profile, a subjective rank is assigned for each of eight environmental profiles to indicate the potential for outsourcing. The rankings range from minus 3 to plus 3 using a matrix. Because some profiles may be more important than others, each profile has a weight assigned to it. The rating given to each factor is multiplied by the factors weight to create a weighted score for each profile (Wilmot et al., 2002).

Pennsylvania Contractibility Model

PennDOT uses contractibility ratings systems (CONTRAS) to rate routine maintenance activities for contracting out potential. Weights ranging from 1 to 5 are given to various factors. The factors considered are given below.

1. Unit cost comparison
2. Degree of labor intensity
3. Existence of critical time constraints
4. Contractor availability
5. Work Volume
6. Planning difficulty levels

7. Requirements for special equipment or skills
8. Amount of inspection required.

The total CONTRAS score can range from a minimum of 17 to a maximum of 53, with higher scores indicating more potential for contracting out than lower scores (Wilmot et al., 2002).

Louisiana DOT

Louisiana DOT has a computer model for outsourcing decision making with qualitative and quantitative components. The first step in the model is the selection of functions for outsourcing. A qualitative analysis is done by considering the following factors.

- External mandates and influences
- Strategic & Organizational Effectiveness
- Organizational Systems & Operations
- Cost & Cost Efficiency
- Human Resources & Organizational Culture
- Vendors Market

Assessment statements are included for each factor. Factors are given weights and a composite index is calculated. A composite index score around 3.0 is decision neutral. Index scores progressively less than 3.0 indicate in-house provision is preferable.

The quantitative model compares the in-house and consultant costs. The program used for this analysis automatically calculates the personnel cost using the median salary rates and payroll additive rate. Similarly, after listing the new and current equipment requirements, depreciation and expense amounts are calculated by the program in light of the agency's capitalization and depreciation policies. A summary of the total in-house cost is provided at the end of the data entry. Besides the contract cost to the outside contractor, revenues or losses generated by the contract are also considered. Both the qualitative index (QI) and the cost index (CI) are normalized so they each range between 0 and 1 (Wilmot et al., 2002).

Oregon DOT

Oregon's model is similar to the one developed by Wilmot et al. for Louisiana, and the only modification is the adoption of a scorecard element for the qualitative model. A Balanced Scorecard (BSC) approach developed by the Harvard Business School (Kaplan and Norton, 1992) is used to assess non-cost factors. The four factors in the original scorecard are:

1. Financial
2. Customer
3. Internal business
4. Innovation and control

Two more elements were added to make it suitable for the public sector. They are employee and contractor market perspectives. Altogether these factors are called six perspectives. A Qualitative index (QI) with a score between 0 and 1 is generated by the computer model. Values below 0.5 favor in-house provision while values over 0.5 favor outsourcing. Six balanced score card perspectives are given in Table 2.5 (Rogge et al., 2003).

Table 2.5: Oregon DOT Six Balanced Score Card Perspectives

Perspective	**Description**
Customer Perspective	Focus on the interests of citizens, legislators, public officials, and special interest groups, and the compliance with laws and regulations related to the function or activity under consideration.
Internal Business Perspective	Focus on agency core competencies, processes, technology capability, and technical expertise
Innovation and Control Perspective	Focus on agency need to monitor and control the function, ability to outsource on a limited basis, and effects on other agencies should outsourcing occur
Financial (Cost) Perspective	Focus on cost aspects, capital investment issues, and timeliness of function or activity under consideration
Employee Perspective	Focus on employee morale, retraining, and relocation
Contractor Market Perspective	Focus on availability of qualified private sector contractors, potential of establishing a "monopoly," and the degree of prior outsourcing experience in the agency for the function or activity under consideration

Source: Rogge et al., 2003

The second phase of the computer model is the cost analysis and is based on the assumption that the program user is familiar with in-house and contractors' cost estimating. In-house costs were separated into direct and indirect costs categories. Direct costs were further split into labor and non-labor categories. Indirect costs include supervision, support services, and general overhead costs. The user answers a series of questions relating to information on in-house costs such as personnel required, amount of time needed, equipment, supplies, materials, and indirect costs (insurance and supervision). Once the costs are sub-totaled, the user is asked to input the estimated cost of contracting out. This includes the costs of letting the contract, monitoring the contractor's performance, and inspecting the work. The computer model uses this information to produce a cost index (CI), with values ranging from 0 to 1. Values below 0.5 favor in-house provision while values over 0.5 favor outsourcing (Rogge et al., 2003).

Wisconsin DOT study

In 2002, Wisconsin DOT and Midwest Regional University Transportation Center conducted a study to assess the outsourcing practices of the private sector and the public sector. Based on the survey results, a balanced score card based model is suggested as given in Table 2.6 (Eger et al., 2002).

Table 2.6: WIDOT Sample Outsourcing Decision Making Scorecard

Service Considered for Outsourcing ______________________________________	
Institutional Setting	
1. Is this a functional part of our core competencies?	____ Yes _____No
2. Does this service need to be provided on a continual basis?	____ Yes _____No
3. Do we have in-house expertise to provide this service?	____ Yes _____No
4. Do we have available workload to provide this service?	____ Yes _____No
5. Can we legally outsource this service?	____ Yes _____No
Risks	
6. Would loss of control of this service harm the organization?	____ Yes _____No
7. Would loss of expertise have a negative impact on the department of transportation?	____ Yes _____No
8. Is quality of service delivery a concern?	____ Yes _____No
9. Would the response to situational problems be reduced?	____ Yes _____No
10. Would current contract performance be negatively impacted?	____ Yes _____No
Goals and Objectives	
11. Can the goals for this service be clearly defined?	____ Yes _____No
12. Are the goals for this service long-term?	____ Yes _____No
13. Can the achievement of the goals be objectively measured?	____ Yes _____No
14. Are objective measures currently in place for this service?	____ Yes _____No
15. If the goals and objectives are not achieved, will this have a negative impact upon the department of transportation?	____ Yes _____No
Provider Evaluation	
16. Are there known external providers for this service?	____ Yes _____No
17. Do the mission and strategic goals of the providers align with the department of transportation mission and strategic goals?	____ Yes _____No
18. Are the providers known to have the capability to provide this service?	____ Yes _____No
19. Has the department of transportation had previous relationships with providers of this service?	____ Yes _____No
20. Are the providers known to deliver high quality services?	____ Yes _____No

Source: Eger et al., 2002

The basic purpose of the score card is to provide an indication of the institutional setting of the organization. The institutional setting is used to identify whether the service to be outsourced is a core competency and has a long term focus. Identification of core competencies helps the decision maker to evaluate non-essential services that are currently provided but have the potential for outsourcing. Non-core competencies are services the organization needs to provide on a continual basis but do not necessarily need to keep in-house. The questions assist the decision maker in determining whether there is a potential for relationship building. Successful outsourcing is a matter of relationship and beyond a specified contract.

TxDOT outsourcing assessment instrument

In 1999, the University of North Texas did a study on the long-term impact and cost effectiveness of outsourcing nine district functions, namely:

1. Base-in-Place repair
2. Paint-and-Bead Striping
3. Information System/Resources
4. Right-of-Way-Acquisition
5. Facilities Management and Maintenance
6. Training, Quality and Development
7. Recruiting
8. Benefits Processing
9. Partnering/Quality Facilitation

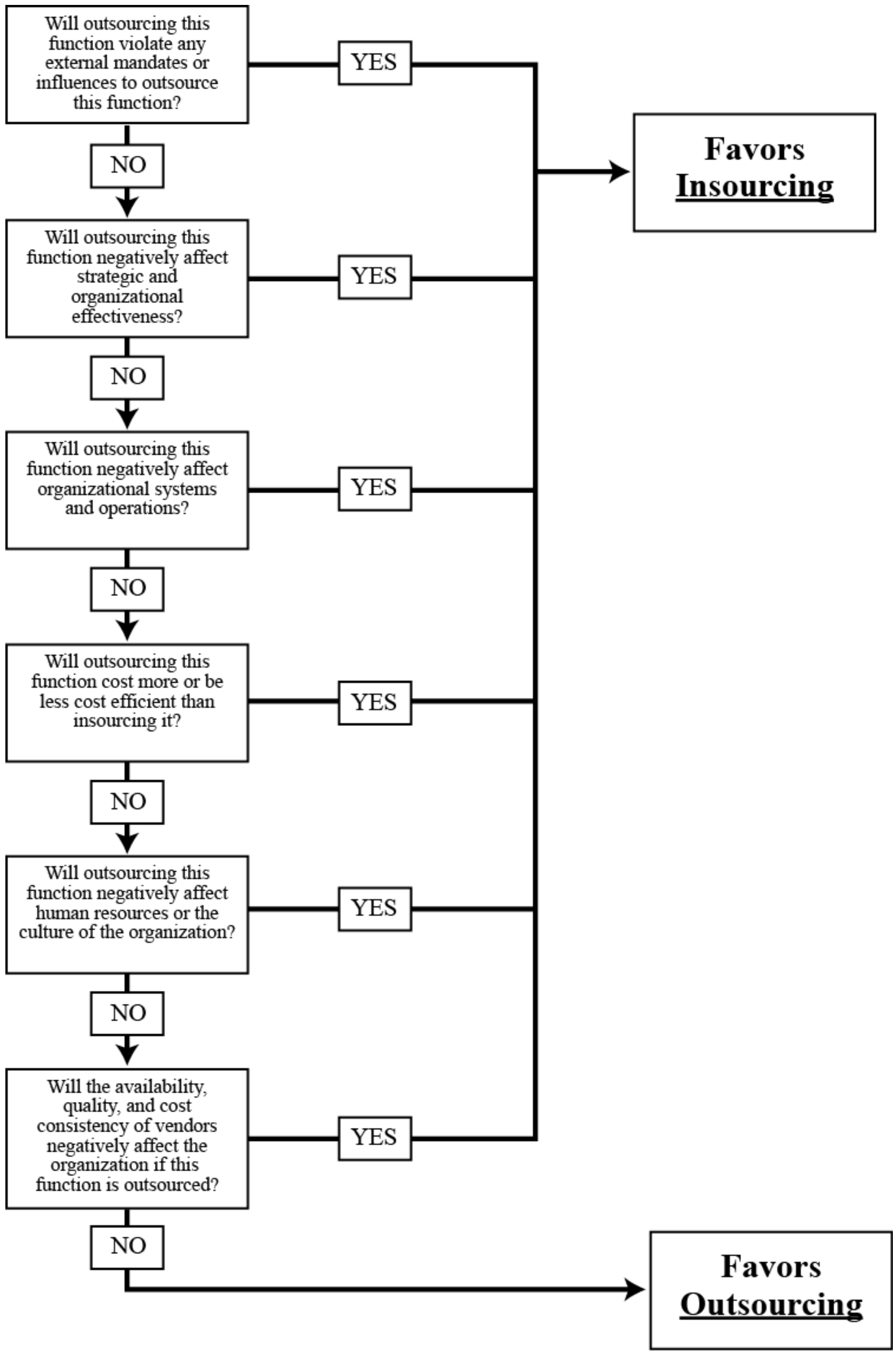
Surveys regarding each of the above functions were conducted among all TxDOT districts. The survey instrument focused on the following factors.

- External Mandates and Influences
- Strategic and Organizational Effectiveness
- Organization Systems and Operations
- Cost and Cost Efficiency
- Human Resources and Organization Culture
- Vendors

The survey found that Base-in-Place repair and Paint-and-Bead striping had high outsourcing potential. As part of the study, the research team proposed two methods to make effective outsourcing decisions. They are a Functional Sourcing Decision Flowchart, and a Functional Sourcing Decision Support Model (Johnson et al., 1999).

TxDOT functional sourcing decision flowchart

Using the flowchart, six evaluation factors are applied individually to each function and a positive analysis response indicates propensity to outsource. According to this model, even if there is an external mandate, in-sourcing may still be justified because of the negativity of the other factors. The flow chart is given in Figure 2.9.



Source: Johnson et al., 1999

Figure 2.8: TxDOT Functional Sourcing Decision Flowchart

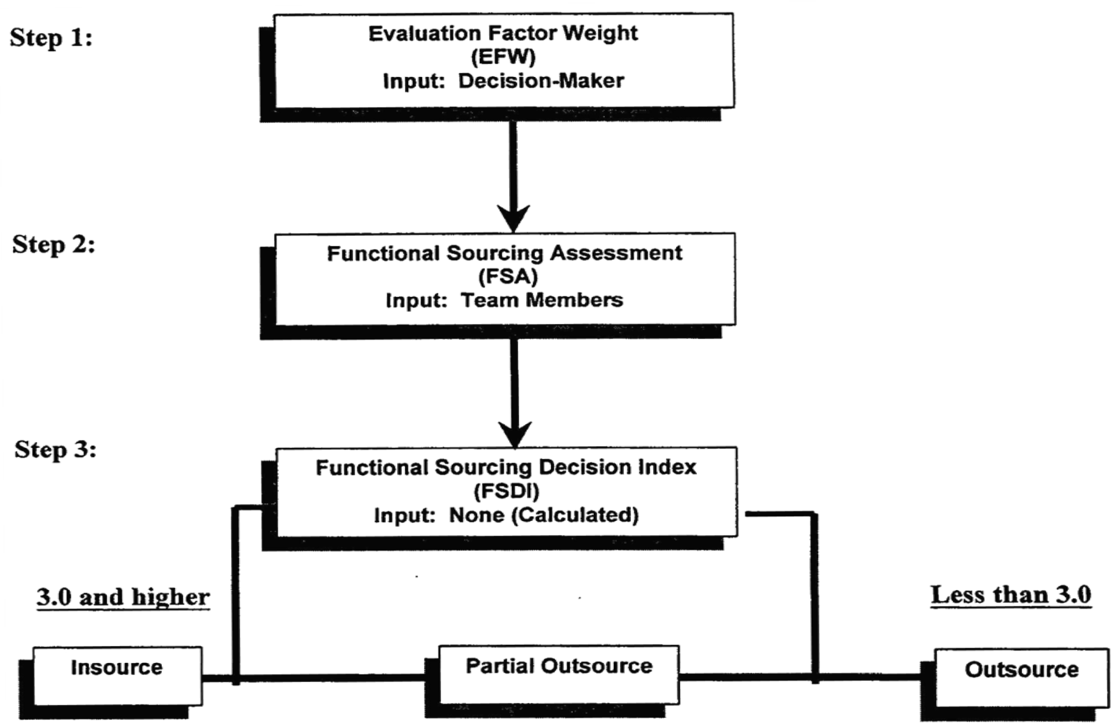
TxDOT functional sourcing decision support model (FSDSM)

This quantitative model is MS Excel based and uses evaluative input from users to assess the outsourcing potential of a function. Three spreadsheets that required inputs from evaluators are incorporated. Detailed description of the steps is given below.

The first step is the completion of the Evaluation factor weights (evaluation of the six factors mentioned above). The evaluators are upper level managers/significant strategists who can offset emotional or external influences that frequently occur in outsourcing decision making. Factors weights are in the range of 0–1.

The next step is the completion of Functional Sourcing Assessment (FSA-30 item check list evaluates the various aspects of outsourcing). Assessments are rated between 5 (strongly agree) to 1 (strongly disagree).

The evaluation factor weights and the functional sourcing assessment results are used to calculate Functional Sourcing Decision Index. If the result is 3.0 or greater the result is favorable to insourcing. If the result is closer to 3.0, partial outsourcing is recommended (Johnson et al., December 1999). A diagrammatic representation of the procedure is given in Figure 2.10.



Source: Johnson et al., 1999

Figure 2.9: TxDOT Functional Sourcing Decision Procedure

These models are generic in nature and can be used for assessing the outsourcing potential of any function.

2.5.5 Section summary

Common outsourcing decision making methods used by the private sector and several DOTs were presented in this section. It was seen that the private sector has developed systematic outsourcing decision making models that evaluate the impact of the decision on the organization. The Strategic Outsourcing Decision Guidebook developed by the NSRP is a good example.

Some DOTs, including Louisiana, Wisconsin, and Pennsylvania, have developed outsourcing decision making models. None of them dealt specifically with the outsourcing of engineering functions. Most of the models are project specific and assess the outsourcing potential of projects individually. TxDOT also developed a decision making procedure for outsourcing maintenance functions. The decision support model consists of a functional sourcing decision flowchart and a functional sourcing decision procedure. However, none of the DOTs have a process for analyzing their entire work program and supporting decisions about what work volume should be outsourced.

2.6 TxDOT's Project Delivery Business Model

2.6.1 Section Objectives

This section provides an assessment of TxDOT's project delivery business model. Methods used by TxDOT divisions and districts to make decisions on project staffing and outsourcing were identified through interviews. The findings and an analysis of the existing practices are also presented.

2.6.2 TxDOT project development process

The Project Development Process (PDP) in TxDOT is a multistep process that may span several years. According to the TxDOT PDP manual 2009, major functions in the PDP are:

1. Planning and Programming
2. Preliminary Design
3. Environmental
4. Right-of-way and Utilities
5. Plans, Specifications, and Estimate (PS&E) Development
6. Letting and Construction

Steps 1–3 are often referred to as Advance Planning. A detailed listing of the activities in each function, and the relevant cost tracking codes is available as an appendix to the original task report.

Planning and Programming

A project begins with identification of a transportation need. Preliminary project authorization allows specific studies to be undertaken. The need for various studies (such as a feasibility study) is evaluated in this step. Ideally, staff requirements for the various functions in the project are also assessed at this time.

Preliminary Design

Preliminary design preparation, data collection, and draft schematics are the important steps in this phase. Traffic studies and field surveys are done as part of design preparation. Preliminary schematic is the step of developing engineering solutions to satisfy the project need. The major products are alternative alignments and typical sections. Hydraulic studies, determination of right-of-way (ROW) needs, and identification of utility conflicts can also be done at this time.

Environmental

This phase identifies the environmental and public impact issues related with the project, and completes the environmental permitting process. This can be a very time-consuming phase.

Right-of-way

Like the environmental phase, ROW acquisition can also be very time-consuming. Owners of property to be acquired are notified and compensation is assessed. Negotiations end with acquisition by agreement or through court condemnation. Owners receive relocation assistance, and parcels are cleared for construction. Contracts are executed with utility owners to relocate utilities.

PS&E Development

Most of the final engineering activities are done in this phase:

- Final Alignments/Profiles
- Traffic Control Plan
- Roadway Design
- Bridge Design
- Drainage Design
- Retaining/Noise Walls & Miscellaneous Structures
- Operational Design
- PS&E Assembly/Design Review

This phase can be relatively short if there is no need to rework previous phases, and can be handed off to a separate design group. Because the previous phases may have dragged on for several years, and 'the end is now in sight' with construction funding lined up, there is always a demand to accelerate this work. Being a staff- and skill-intensive phase, it is always a candidate for outsourcing.

Letting and construction

In final processing, the completed PS&E package is reviewed by the Design Division, with involvement from the Traffic Operations, Construction, and General Services Divisions as needed. Upon approval, contracts are advertised, and after a bid period and review, a contract for construction is executed in accordance with state rules (PDP manual, 2009).

2.6.3 TxDOT project types

TxDOT classifies projects according to design type in its Design and Construction Information System (DCIS). There are a total of 35 project types in DCIS, of which the 27 types used in FY 2006–07, numbers of each, and total construction volumes, are given in Table 2.7. It is seen that the most common project types by number are Miscellaneous Construction, Safety, and Bridge Replacement. By dollar volume, the biggest are Safety, Widen Non-Freeway, and Rehabs.

Table 2.7: Summary of TxDOT contracts let in FY 2006–07

DCIS Code	Project Type Description	No of Projects	(Contract Amount + Change Orders)
BCF	Border Crossing Facility	1	$4,345,638.04
BR	Bridge Replacement	236	$608,983,868.40
BWR	Bridge Widening Or	55	$222,272,397.38
CNF	Convert Non-Freeway To Freeway	7	$301,692,143.84
CTM	Corridor Traffic Management	14	$62,471,234.99
FBO	Ferry Boat	1	$22,512,000.00
HES	Hazard Elimination & Safety	4	$5,240,528.55
INC	Interchange (New or	28	$787,298,018.28
LSE	Landscape and Scenic	83	$41,463,949.04
MSC	Miscellaneous Construction	349	$818,837,999.76
NLF	New Location Freeway	1	$67,466,929.41
NNF	New Location Non-Freeway	12	$193,373,350.63
OV	Overlay	184	$611,568,634.47
RER	Rehabilitation of Existing Road	192	$1,013,188,529.29
RES	Restoration	50	$167,257,222.79
ROW	Right-of-way	2	$146,173,826.42
SC	Seal Coat	85	$460,855,529.66
SFT	Safety Project	311	$1,064,450,294.13
SKP	SKIP (Exempt from sealing – Transportation Enhancement	6	$8,488,995.93
SRA	Safety Rest Area	3	$42,035,563.16
TC	Tunnel Construction	1	$165,509.87
TDP	Traffic Protection Devices	4	$8,214,080.41
TS	Traffic Signal	57	$31,839,098.29
UGN	Upgrade to Standards Non-	13	$68,956,309.65
UPG	Upgrade to Standards Freeway	12	$186,878,396.43
WF	Widen Freeway	14	$825,697,696.07
WNF	Widen Non-Freeway	70	$1,049,760,200.79
Total		**1795**	**$8,821,487,945.68**

2.6.4 TxDOT PE contracts

Procedures used by TxDOT for contracting PE work are typical of most DOTs. All state and local departments of transportation that procure engineering and design consultants for projects with Federal-aid highway funding are required to follow the Brooks Act. According to that Act, all professional services including preliminary engineering, feasibility studies, design, engineering, construction management, etc. are to be procured through Qualifications-Based Selection (QBS).

TxDOT's Consultant Contract Office (CCO)

The director and assistant director of CCO were interviewed in May 2009. The CCO in TxDOT's Design Division manages three types of professional services contracts: Engineering, Surveys, and Architecture. TxDOT actually uses nine types of professional services contracts, the other six contract types being handled by other departments. CCO is in charge of allocating the PE budget for each district. The group also assists the districts with consultant selection, negotiation, and execution of contracts. Because most (90–95%) of the funding for consultant work comes from the state, all functions are done in compliance with state laws.

Before district PE budgets are allocated annually, the CCO typically requests all districts to give projections about their consultant contract needs based on the three year letting schedule. When this process is used, CCO prepares a detailed spread sheet of the three year letting schedule and sends it to districts. Districts forecast their contract needs for the future based on the expected projects and resource availability. For example, they might project their need for survey contracts at $5 million. This would be the total amount of survey contracts needed over the 3 years (not for one specific project).

After receiving the projections from districts, CCO assesses the need and makes decision regarding the funding. The funding allocation decision mainly depends on the projected needs identified in addition to the consideration of historical spending of the district and total available funds. Although the CCO helps districts in conducting negotiations with consultants, it is never involved in the selection of projects to be outsourced.

TxDOT PE contract types

There are basically two types of consultant contracts used by TxDOT for PE work, evergreen and project-specific contracts. A third type, the Comprehensive Development Agreement (CDA), is a recent development.

<u>Evergreen contracts</u>

These are indefinite delivery contracts that provide for an indefinite quantity of specific services to be furnished during a two-year period with a limit of $2 million of fees that can be awarded to each consultant. For these contracts, the general scope of services (for example, bridge design or hydraulics) that the consultant is approved to provide and the hourly and unit rates are specified in the evergreen contract language. Indefinite deliverable type contracts are priced based on the hourly rates, fees, and overhead rates. Of these contracts, 70% are discipline oriented and they reduce procurement time and increase efficiency (Deloitte, 2007).

<u>Project-specific contracts</u>

Project-specific contracts are based on a single project and include a detailed project-specific scope and rates.

<u>Comprehensive Development Agreements (CDA)</u>

CDAs are a relatively new contracting development and delivery model that TxDOT has begun to utilize to develop, design, construct, operate, maintain, and/or finance transportation facilities. The three primary types of CDAs used by TxDOT are Design-Build (DB) Agreements, Pre-Development Agreements, and Concession Agreements. TxDOT provides oversight for CDA projects and it may retain consultants to help with oversight responsibilities. The oversight team helps to facilitate procurement, construction, and operation of the new project and may also provide independent quality verification for design and construction. As a development and delivery methodology, CDAs at the District level can impact project development functions, project delivery functions and support operation including design, construction, maintenance, and finance. On current CDA projects, particularly concession projects, inspections are performed by an independent engineer who is reimbursed by both TxDOT and the concessionaire. There appears to be confusion as to whether or not TxDOT inspectors are responsible for performing inspections on CDA projects (Deloitte, 2007).

2.6.5 Consultant selection procedure

TxDOT procures its Architect/Engineer contracts through a procedure called Qualifications-Based Selection (QBS). The first step in consultant selection process is a request for use of provider services submitted to the Design Division for approval to hire a consultant. Then, a notice of intent is submitted and published to inform consultants of need for services, and consultants submit letters of interest. All interested parties are provided with a request for proposal in providing the service. A list of consultants is prepared after reviewing the proposals. During the evaluation, the proposals are reviewed for precertification requirements, scored for content and quality, and ranked. The consultants are short listed based a clear break score required to perform interviews and formal proposals. Interview and proposal packets are submitted to all short listed consultants. The proposals are reviewed and scored and subsequently interviews are conducted to select the most qualified consultant.

After the final selection of a consultant and their consent, negotiations of the scope and fees for the services provided are done. If the negotiations are not successful, the consultant with the next highest core will begin new negotiations for scope and fee. All major steps of this process are submitted to the Design Division for review and approval. Negotiation considers the primary cost factors like hourly rates by labor classification, profit margins, overhead rates, and work hours.

- <u>Hourly rates by labor classification</u>. It is difficult for TxDOT to negotiate over hourly rates because some firms include benefits as a part of the hourly rate and others consider it as a part of overhead rate. Besides, TxDOT does not have a data base to compare past data, which makes the negotiations difficult.

- <u>Profit margins</u>. The profit margins are regulated to be between 12 to 15% of salary and overhead on all projects but TxDOT lacks a systematic approach to set a profit margin for projects. This may be a reason for an increase in the outsourcing cost for at least some contracts.

- <u>Overhead Rates</u>. Negotiations over overhead rates are not permitted for federally funded projects and on state funded projects it varies between 160 to 200%. The negotiations over overhead rates depend on the skills of TxDOT engineers and hence there are chances that they end up with unrealistic costs. A study done by Dye Management group reveals that, overhead costs went up in 12% of projects after negotiations.

- Work hours. TxDOT's estimate of hours depends on the time availability of the negotiator and other team members, and is not always well-prepared, primarily due to experience and time constraints. It is difficult to negotiate unless there is a well defined scope of work.
- The Brooks Act and QBS in general limit TxDOT's ability for meaningful negotiation (Dye, 2008).

2.6.6 TxDOT recordkeeping

As in most DOTs, TxDOT maintains an account-keeping system with the help of a variety of software programs and procedures. TxDOT uses Site Manager to track all aspects of construction projects. The American Association of State Highway and Transportation Officials (AASHTO) developed the Site Manager program to automate the construction contract administration functions for construction and maintenance projects from the time a contract is let through close out.

The Design and Construction Information System (DCIS) is a legacy system used during preliminary engineering on construction projects and is used to produce project estimates and plan letting schedules. This system also contains contract information on completed jobs and thus serves as a historical database for work performed in each district.

TxDOT tracks the cost of independent projects using the cost system called Financial Information Management system (FIMS). FIMS is a legacy system that records accounting events and is used state-wide for recording financial information. From a district perspective, FIMS is used for processing payments at headquarters. The system compiles overall project costs and produces ledger reports. The Control Section Job (CSJ) is used to track to identify the individual projects and track the associated costs such as Preliminary Engineering, Construction Engineering, Right-of-way, and Construction. The PE costs represent the direct engineering costs on individual projects during the planning and design stages including a multiplier to account for costs associated with fringe benefits, sick, vacation and leave time, etc. CE costs are reported in FIMS when employees, equipment, and other services such as outside laboratory testing are charged to construction contracts (Deloitte, 2007).

TxDOT is currently developing a project cost tracking system that is intended to monitor costs related to preliminary engineering, construction, right-of-way, bond finance, construction engineering, and contingencies. It is being developed within the current system, DCIS. One district already has developed a cost monitoring system called Total Cost system—"ProtoCost" (Deloitte, 2007).

Consultants are typically paid on deliverables. Consultants submit an invoice to the design project manager who checks the accuracy and completeness of the deliverables and verifies that the invoice reflects the work completed. If required, the project manager may request additional information or drawings prior to signing off on the invoice. Internally, some districts are experiencing delays and inaccuracies in the plan reviews conducted by the area office design sections on consultant design submittals (Deloitte, 2007).

2.6.7 Current project delivery practices in TxDOT

In the existing business model for project delivery in TxDOT, in-house staff and consultants both have significant roles. Apart from the CCO, key players in the project delivery process are the district Transportation Planning and Development (TP&D) Section, the district Consultant Contracts office, district Central Design, and area design offices.

Project delivery practices in TxDOT districts—data collection

Data regarding project delivery practices of TxDOT districts were collected through a questionnaire (see Appendix C) and interviews in June–September 2009. Questionnaires were distributed to all districts. A total of eighteen responses were collected. District mode of response and interviewees are given in Table 2.8.

Twelve districts (Amarillo, Bryan, Brownwood, Childress, Odessa, Laredo, San Angelo, Houston, Fort Worth, Paris, Tyler, and Pharr) scheduled telephone interviews after receiving the questionnaire. Interviewees included the district TP&D director and other key planning staff such as Assistant Director of Design or Director of Consultant Contracts. The interviews took 45–60 minutes. After the responses were documented by the researchers, the interviewees got a copy by email and had the opportunity to make corrections.

Six districts (Beaumont, Lufkin, Lubbock, El Paso, San Antonio, and Atlanta) responded by emailing their answers in the questionnaire. Of these six, the researchers did telephone interviews with San Antonio and El Paso to clarify the answers.

Table 2.8: District Response Mode and Interviewees

District	Mode of response	Interviewees
Amarillo	Phone interview	Tracy D. Cain, District Design Engineer
Atlanta	E-mail response	Lance Simmons, District Bridge / Special Projects Engineer
Beaumont	E-mail response	Phillip Lujan, Director TP&D
Brownwood	Phone interview	Elias Rmeili, Director TP&D
Bryan	Phone Interview	Bob Appleton, Director TP&D
Childress	Phone interview	Martin R. Smith, P.E, Director, TP&D
El Paso	E-mail response, telephone follow up	Charles H. Berry, District Engineer
Fort Worth	Phone interview	William C. Riley, PE, Director TP&D
Houston	Phone interview	Gabe Y. Johnson. P.E, Director TP&D William Brudnick, P.E, Asst Director of Design
Laredo	Phone interview	Alberto Ramirez, P.E. (Interim), TP&D Director
Lubbock	E-mail response	Jerry W. Cash, P.E, Advance Project Development Engineer
Lufkin	E-mail response	Cheryl P. Flood, P.E, Director TP&D
Odessa	Phone interview	Gary J. Law P.E., Director TP&D Matt Carr
Paris	Phone interview	Ricky Mackey, Director TP&D
Pharr	Phone interview	Jody Ellington, Director TP&D
San Angelo	Phone interview	George R. Herrmann, P.E., Advanced Project Development Engineer District Hydraulic Engineer
San Antonio	E-mail response, telephone follow up	Lizette Colbert , Director TP&D Gregg Granato, District Design Engineer
Tyler	Phone interview	Vernon Webb, Director TP&D

Project delivery practices in TxDOT districts—findings

The interviews indicate that, generally, formal analytical techniques are not used by the districts to manage project delivery. Managers rely on their experience to assess workload and to decide what can be done in-house and what must be outsourced.

Staff requirement analysis

The initial step in project delivery decision making is the assessment of skills and resources needed for the future program of work. In the Bryan district, man-hours required for a particular program are calculated considering factors such as scope of the work, construction cost, past experience from similar projects and time required to complete the work.

However, many districts follow a simplistic rule of thumb: $x construction dollars per designer annually. In this method, the total estimated annual letting volume is divided by x to give the number of full-time designers needed. Annual variations may be averaged out over 3–5 years. A widely quoted value of x in the districts is $5 million, i.e., each designer is expected to generate $5 million of construction plans annually. The basis for this number is not clear.

The $5 million per designer benchmark seems to apply only to in-house design productivity, not consultants. Presumably, if a district has a projected letting volume in excess of the in-house capability, the excess work could be outsourced. It is obvious that such a rough benchmark does not address the need for specific skills, the efficiency of project teams, or the comparatively high resource requirements per $ million for small projects. Some districts deal with these issues by analyzing staffing for specific projects or functions.

For project level staffing analysis, type of project, location of the project, and past experience are the factors considered. Some districts examine similar past projects and request the opinion of experienced personnel. For example, in the Paris district, design team leaders and the director of TP&D assess the calendar time of projects and estimate the requirements based on their knowledge and experience from similar projects.

However, not all phases of a project require the same skills. Therefore, an analysis is needed at the function level for each of the unique engineering skills needed. This analysis would be a refinement of the project level staffing analysis, with a manpower demand chart over time for each skill. None of the districts utilize such a system. Instead, projects that require advance planning and specialized engineering are separated from regular projects, and slated for outsourcing if the skills are not available in-house. If the skills are available, those projects are placed in the queue for those specialized personnel. Those special groups may do their own workload analysis and decide whether those projects can be done in-house or outsourced.

<u>Estimation of in-house capabilities</u>

Typically a team of two or three staff members would work on a project until their portion is finished, then pass it on to the staff responsible for the next phase. In many cases designers get involved only at the PS&E stage. Larger districts have design teams of about 10 people, and they work on 3–4 projects at a time. Thus, it is relatively easy to know whether a team can take on another project. However, because this assessment is at a work function level (typically, the PS&E function), it provides little information on the overall project staffing needs and the likely completion schedule. It is imperative that districts keep track of the status of projects in order to assess staff demands/availability.

In the El Paso district, projects are scoped at a scoping meeting and then scheduled by availability of funding. Projects are assigned to available design groups with the skills and experience necessary to produce the type of project. Projects are individually scheduled each quarter of the fiscal year. Active projects are scheduled to include durations for individual activities such as environmental documents, ROW, design, and PS&E processing. Completion dates and durations related with processing PS&E by district and Austin HQ are included in project scheduling.

In a few districts, the availability of individual designers is checked. The Odessa district uses compensatory time to achieve the demand/target for a fiscal year. The man-hours are accumulated when there is a surge of projects and people are allowed to have time off during periods of low work volume.

Table 2.9 summarizes tools used by districts for managing their work programs.

Table 2.9: Analysis tools used by districts

District	Program requirements	In-house staff availability
Amarillo	$5 million rule of thumb	$5 million rule of thumb
Atlanta	Personal judgment	Bar charts for individual designer
Beaumont	Personal judgment	Personal judgment
Brownwood	$5 million rule of thumb	$5 million rule of thumb
Bryan	Personal judgment	Calendars and spread sheet
Childress	Highway Performance Tracking and Monitoring System (HPTMS)	$5 million rule of thumb
El Paso	Personal judgment	Personal judgment
Fort Worth	Primavera, $5 million rule of thumb	$5 million rule of thumb, schedules, P6
Houston	Personal judgment	$5 million rule of thumb
Laredo	Suretrack for developing schedule	$5 million rule of thumb
Lubbock	Personal judgment	Personal judgment
Lufkin	PDMS	PDMS
Odessa	Personal judgment, PDMS	Personal judgment
Paris	Personal judgment, PDMS	$5 million rule of thumb
Pharr	Personal judgment	Personal judgment
San Angelo	Personal judgment	Past experience
San Antonio	Personal judgment	$5 million rule of thumb
Tyler	Personal judgment	Design schedule

In a couple of districts, calendars and spreadsheets are used to assess staff availability. Atlanta and Tyler districts use a design schedule to check the availability of designers. Tyler's design schedule has milestones of 30%, 60%, and 90% completion. In Beaumont, area office make decisions that are verified by district TP&D office. The design work is distributed to the area offices, and annually, they are asked to review their projects, work load/resources, and projects outside their ability to develop. Laredo uses Suretrack to develop the schedule. A sample Suretrack output is given in the original task report.

Childress district uses a tool called the Highway Performance Tracking and Monitoring System (HPTMS), which was developed by the Corpus Christi district. HPTMS gives information on the duration of each phase of project development, and the manpower (designers) needed for all types of projects. Its output is in a graphical format showing which designer is working on which project and when they will finish the project. A screenshot of HPTMS output is given in the original task report.

Fort Worth district uses Primavera P5 for project planning. This first-generation Project Development Management System (PDMS) was expanded for department use in tracking project development milestones on projects under development in FY 2009–2012. TxDOT is working on the second-generation of PDMS that will utilize Primavera P6 software for managing highway design projects throughout the department (TxDOT response to sunset report, 2008).

According to TxDOT, PDMS provides a consistent way to monitor design/construction projects and to track and manage work performed as it is being developed by various offices. It can track both work performed within a district or with outside staff. The primary users are project managers in districts to deliver design/construction projects on schedule. One FTE would be needed to track projects in a district of 25 FTEs if the tracking were done manually (Quality Assurance Team (QAT) Annual Report, 2008). Childress, San Antonio, and Lufkin districts utilize PDMS to determine availability of designers versus proposed letting date. Most of the districts anticipate that proposed PDMS will be helpful.

Selection of work to be outsourced

All districts are mandated to outsource 35% of annual PE expenditure, and the actual engineering outsourcing volume in all districts is above 35%. In big districts like Houston and Fort Worth, it is 60–70%.

Most districts do not have a formal approach regarding outsourcing decision making. Experience and personal judgment are the common tools for assessing the outsourcing potential of functions. In Bryan, the decision making team consists of Director of TP&D, design engineer, environmental, advanced planning engineer, ROW administrator, district bridge engineer, and district design team leaders. Work allocations and outsourcing decisions are done based on the knowledge of the decision making team. The plans are approved by the District Engineer.

However, in most of the districts, outsourcing decisions are made by the district Director of Transportation Planning and Development (TP&D). In the Lufkin district, Central Design Team supervisors, the Director of Traffic Operations (when applicable) and Area Engineers use the following procedure: the available design capacity and abilities are reviewed and a determination is made whether in-house design capabilities are available to meet program deadlines. The final decision regarding outsourcing is made by the TP&D director.

In the San Antonio district, preliminary engineering work is performed out of the District's Advance Planning group. The District Design Engineer determines the design team most qualified and available to complete a project. The work is distributed to ensure that the in-house staff is maximized before deciding to outsource any projects. It is also decided if there is enough consultant budget to outsource that project. There are times that a project is slated to be designed in-house but to meet letting goals a particular task/function might be outsourced. Work can be accelerated by contracting out because consultants can increase the resources quickly.

The El Paso district uses a district-prepared quarterly project development schedule that includes tasks for schematic, environmental document, right-of-way acquisition, and PS&E. Projects are placed for let date and design development schedule is backed in to match the let date. If the in-house schedule cannot meet the let date, a consultant contract is chosen.

Similar methods are generally used to prepare the consultant budget spreadsheets for CCO. The decisions are made by TP&D directors. For most of the districts, the budget allocation from CCO is sufficient. If there is a lack of funding, some of projects will be put on hold or cancelled. Letting schedule, construction funding, and third party involvement in the funding are the factors affecting the prioritization of projects if there is a lack of consultant funding.

In El Paso, work plans are revised to keep the program efficient and on schedule. Adjustments are coordinated with DES/CCO after 50% of the work has been completed to ensure additional funds are not needed sooner. Lubbock has a different approach. The preferred method is to request an Advance Funding Request prior to the finalization of the budget.

Factors influencing TxDOT district outsourcing

Apart from the mandate to outsource at least 35% of PE, the districts cited a number of reasons for outsourcing work:

- Expertise/ learning curve of in-house staff
- Number of employees available
- Scope for training and development
- Project duration/Letting schedule
- Availability of funds/ Funding allocation from CCO/ time to select consultants
- Complexity of the project
- Lack of in-house equipment.

Some small districts contract out some types of work because it requires a long time and does not merit a full-time staff person. Odessa outsources planning projects (schematics, highway capacity analysis, corridor planning) and hydraulics because of the long duration. Others mention the desire to learn from consultants. Lubbock contracts out route studies and mobility studies to get a different perspective. Many small districts do not have enough complex projects to provide training or to retain specialized skills. Even larger districts like Houston outsource functions like bridge design to supplement in-house capability.

Functions outsourced and reasons

Of all the reasons for outsourcing mentioned, four are the most frequently given as the reason why specific functions have to be outsourced:

- Lack of equipment
- Lack/shortage of staff
- Lack of expertise/skills/experience
- To supplement in-house capacity.

Table 2.10 gives the functions that are outsourced, the districts that do so, and the primary reasons.

Table 2.10: Functions outsourced by districts and reasons

Functions Outsourced	District that Outsource Functions	Primary Reason
Feasibility studies	Brownwood	Lack of equipment
	Lubbock	Lack of staff
		Supplement in-house
Advanced planning	Pharr, Tyler	Lack of skills in-house
Large mobility	Laredo	Lack of staff
Long term freeway	Lubbock	Lack of skills in-house
		Supplement in-house
Schematic Design	El Paso	Lack of equipment
	Lufkin	Lack of staff
Environmental	San Antonio	Lack of equipment
	Amarillo	Lack of skills in-house
Surveying, Mapping	Houston, Odessa	Supplement in-house
ROW Mapping	San Angelo	Lack of skills in-house
	Atlanta	Lack of staff
Surveying	Amarillo, Brownwood, Childress, El Paso, Laredo, Pharr, San Antonio	Lack of equipment
	Beaumont, Paris, Atlanta	Lack of staff
Utility design and coordination	Houston	Lack of skills in-house
Geotechnical	Laredo, Paris	Lack of equipment
	Houston	Lack of skills in-house
Hydraulics	Bryan, Houston	Lack of skills in-house
	Odessa	Supplement in-house
Hydrology	Bryan, Houston	Lack of skills in-house
Bridge Design	Amarillo, Bryan, Laredo, Lufkin, Paris, Tyler	Lack of skills in-house
	Houston, Odessa	Supplement in-house
Interchange projects	Odessa, Tyler	Lack of skills in-house
Roadway Design	Lufkin	Lack of skills in-house
Traffic Engineering	Houston	Lack of equipment
	Lufkin	Lack of skills in-house
Illumination design	Lufkin	Lack of skills in-house
	Odessa	Supplement in-house
PS&E Production	Atlanta	Lack of staff
CPM Review	San Antonio	Lack of equipment

District PE contracting and management

As described in an earlier section, two types of contracts are mainly used by TxDOT for PE work: evergreen contracts, and project specific contracts. In selecting a contract type, the size and complexity of the project are the biggest factors. The decision on contract type is made by the district Consultant Administrator, Director of TP&D, and the responsible Area Engineer.

On an average, 7 months are needed to finish the process of consultant selection. To do negotiations for definite deliverable contracts, districts need to be knowledgeable about the final product. Hence only specific projects are done using definite deliverable contracts. Most of the PS&E, Feasibility studies, and Route studies contracts are definite deliverables. Districts like Childress, Paris, and Houston prefer definite deliverable type for PS&E because the district knows the requirements.

The lengthy and tedious consultant selection process is a district concern. Most of the districts interviewed prefer indefinite deliverable type contracts due to their flexibility. Indefinite deliverable type contracts have the advantage of keeping consultants on call. In such contracts, once a consultant is hired, the work can be started within a month. Indefinite deliverable type contracts are preferred for surveying because the deliverables are unknown. Most of the survey contracts are evergreen contracts for a period of 2 years. Sometimes consultants on indefinite contracts from other districts are hired. In such cases the district has to negotiate a work authorization.

The disadvantage of an indefinite deliverable contract is that the size and duration is limited. In an Executive Memo issued by TxDOT's Executive Director on May 5, 2005, the Administration limited the size of indefinite deliverable (evergreen) contracts to increase contracting opportunities for firms, especially small business and minority firms. According to current rules, evergreen "indefinite delivery" contracts cannot exceed $5,000,000 for border districts (El Paso, Laredo, or Pharr) and metropolitan (Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, Lubbock, Pharr, or San Antonio) districts. For other districts, the maximum amount payable is $2,000,000. The maximum duration is 2 years. Under unique circumstances in a metro/border district or division, request can be submitted to CCO for a higher limit.

Districts usually track contractor billings using spreadsheets. All the invoices are entered and matched against the budget. Sometimes, the Financial Information Management System (FIMS) and Budget Information System are used for tracking consultant costs. The costs are charged to job function 164. Indirect expenses are charged to overhead. Once the consultants are selected, expenses are charged to a specific project CSJ number. For evergreen contracts, the expenses are charged to the particular project CSJ number for which the work is done. Expenses incurred before selecting the consultants (e.g., RFPs, prequalification, etc.) are charged to overhead. This work is handled by the district's Consultant Contract Administrator.

In Odessa, the cost tracking method mainly depends on the type of contract signed with the consultants. In the case of cost plus fixed fee contracts, consultants submit monthly reports of overhead and expenses. For lump sum contracts, the district negotiates with consultants based on the products/project milestones, payment schedule, and rates. Consultants are paid after the product (finishing project/milestones) is accepted by TxDOT. Lump sum contracts are preferred over cost plus fixed fee contracts. The cost of oversight is charged to the project function "Management of contracts."

Districts indicate that their overhead on consultant contracts is usually 6–7%, but has in some cases been as high as 21%. In Brownwood, the ratio is 15% of an in-house employees' time for each consultant FTE on the project. Many districts do not monitor the cost of overhead on consultant contracts.

Opinions about in-house/consultant balance

The districts generally hold the view that a good balance of work in-house and outsourced is mutually beneficial. A certain amount of work should be done by consultants to keep them familiar with TxDOT requirements, and to maintain district negotiating and consultant management skills. At the same time, a certain amount of work needs to be done in-house to develop and retain engineering expertise, and to provide the experience needed for upper management in the organization. The districts hold differing opinions as to what the minimum in-house volume should be, as shown in Table 2.11.

Table 2.11: Minimum PE work to be kept in-house

District	Opinion on minimum level of in-house work
Amarillo	65% statewide
Bryan	At least 50%
Childress	80%
El Paso	67%
Houston	50%
Laredo	85%
Lubbock	Should vary with no minimum
Paris	As much as possible
Pharr	70%
San Angelo	At least 50%
San Antonio	50%
Tyler	65%

In most cases these numbers are higher than current values, suggesting that the districts would prefer to keep more work in-house. While none of the districts said they would need more staff to do this, that implication is suggested by their statements that they outsource because of staff shortages. On the other hand, none of the districts said that 100% should be done in-house, indicating that they see consultants as an essential element of project delivery strategy.

2.6.8 Analysis of TxDOT's project delivery model

There are strengths as well as weaknesses in the project delivery model used by TxDOT districts. These attributes provide opportunities for improvements, but also create some concerns.

Strengths of TxDOT's project delivery model

Skilled and experienced staff: In-house staff is generally highly skilled and experienced, and able to accomplish any TxDOT project. District engineers and TP&D directors say they have a clear understanding of their workload and capabilities, and where to best utilize their staff. Such qualitative judgments are necessary even in formal decision making processes, and help in matching projects to the best teams, whether in-house or consultant.

High morale: In-house engineers are confident that they complete projects just as efficiently as consultants. Urban districts like Houston say that their in-house teams are superior, but have to outsource some work only because of lack of staff.

Desire career development: Some district managers (e.g., Odessa) consider the career development of in-house engineers very important, and try to keep some challenging projects in-house.

Accountability: All the district interviewees stressed that they take their responsibility as stewards of taxpayers' money very seriously. Some expressed concerns over the quality and cost-effectiveness of contracting out engineering. They would prefer that only routine projects be given to consultants so that they can handle the more complex projects in-house.

Positive attitude to consultants: Districts welcome the use of consultants to supplement in-house staff during peak work volume and for certain projects. Keeping full time staff for rare/long term work is not considered cost-effective. Districts say that a certain amount of consultant contracts are needed to maintain their negotiation and consultant management skills. Likewise, a minimum stream of work to consultants is necessary to keep the latter familiar with TxDOT requirements.

Weaknesses

Simplistic assessment of work program requirements: The districts suffer from uncertainty over construction and consultant funding and are unable to plan their 3–5 year work programs effectively. Project letting dates are mostly guesses, and change frequently because of factors beyond district control. Districts use a simplistic benchmark that one designer can generate $5 million in construction plans annually to estimate staffing needs. However, studies have shown that project cost is not linearly proportional to engineering effort. Moreover, the $5 million standard is applied only to in-house staff, not to outsourced work.

Qualitative assessment of in-house staff availability: Personal judgment and verbal feedback are the preferred methods to determine how busy in-house staff is. The districts rarely attempt to determine the status of current projects and the resources needed to complete. As a result, the districts lack efficacy in identifying workload gaps and in planning assignments. A transparent method for reporting project status is needed.

Unstructured outsourcing assessment: Districts do not follow a structured approach for deciding what work should be done by consultants. The current approach is driven by the 35% mandate, available consultant funding, and ad hoc decision making. A rational procedure should include assessments of staffing needs and project schedule. District training needs and long-term in-house capabilities should also be considered.

Mandatory outsourcing: Districts are required to outsource at least 35% of their PE work, and small districts do so even if they have capacity. In such cases, outsourcing results in loss of in-house competencies and the ability to oversee consultants properly. To ensure the benefits of consultant involvement in the districts, a minimum level somewhat lower than 35% should be established for smaller districts. Conversely, to ensure in-house viability, a maximum should also be established, especially for larger districts.

Lack of guidelines: Districts do not have clear guidelines regarding outsourcing. While many districts oppose the idea of mandatory rules, a rationalized procedure would reduce ambiguities and help in achieving the anticipated benefits of outsourcing.

Tedious consultant selection process: Selection of consultants for district projects is a long process. In one district manager's words:

> "Our greatest problem with our current system is the amount of time required to hire a consultant to perform the work. In most cases, the selection process from notice of intent to actual contract execution is between six months to a rare example of over a year. Several checks and balances are included to ensure a fair and equitable selection is ensured. The major problem is the time for Division review of the process at each critical step."

All districts pointed out that this is a major hindrance to managing the in-house/consultant balance. Because they are only able to procure consultants for long lead-time projects (e.g., added capacity), they have to assign the quick turnaround projects (bridges, rehabs, etc.) to in-house staff. Smaller projects actually require more engineering per construction dollar.

Restrictions on indefinite deliverable contracts: Indefinite deliverable contracts are preferred by the districts due to the tedious consultant selection process, but have dollar and duration limits. These restrictions reduce the ability of districts to use outsourcing effectively.

Insufficient performance assessment: The Deloitte report (2007) noted weaknesses in the existing district performance appraisal system. The districts do not have realistic engineering productivity benchmarks or evaluations of productivity. Similarly, even though in-house employees spend a significant amount of time overseeing consultant work and the overhead costs incurred are recorded, no evaluations or benchmarking of this activity are done.

Opportunities

Consultant market: TxDOT's outsourcing model is favorable towards consultants, with a minimum quota of 35% in each district, and percentages as high as 70% in districts like Houston. Consultants have the skills and capacity to handle TxDOT work, and they are able to ramp up resources within a short span of time to meet demanding schedules. These capabilities make them good partners for TxDOT to enhance its capacity as needed. Consultants are available to work in all TxDOT districts.

Contracting flexibility: Districts have a choice of project-specific or indefinite deliverable contracts. They prefer the latter because a consultant is available when needed, and can start work almost immediately. In many cases districts piggy-back on indefinite deliverable contracts from other districts to bring in already-approved consultants, especially for projects in which personnel location is not an issue.

Regionalization: Currently, some of the large districts farm out work to other districts during workload peaks, because that gets the work started sooner than hiring consultants. TxDOT's recent regionalization initiative will pool certain functions and resources, including consultant contracting and management, making more specialized personnel available and increasing efficiency. It will reduce the inefficiencies of each district having to outsource 35% of its work, which could actually decrease the amount of work going to consultants. Regionalization should also provide more opportunities for staff from small districts to work on challenging projects and pursue wider career paths.

PDMS: Some districts have started incorporating programs like Primavera and other planning software for requirements planning and resource analysis. Most districts anticipate that, once implemented, PDMS will aid in decision making.

Concerns

Resistance to change: At least half of the responding districts do not see a need to change the way they manage their resources. It appears that they overvalue personal judgment and ignore analytical approaches. This attitude could make it difficult to implement any initiative to improve decision making. In fact, they fear that guidelines or checklists will eventually become standardized procedures (like the consultant selection process) and create more delays.

Resources: Managing consultants consumes significant district resources and reduces in-house productivity. The districts feel that TxDOT administration may not be aware of this: it is not simply a matter of handing off work to consultants and still expecting full productivity in-house. CCO paperwork is also time-consuming. Moreover, even though the districts have staff with excellent technical skills, they are short on negotiation and management skills for properly managing consultants. The districts are concerned that the current outsourcing paradigm reduces their ability to keep challenging projects in-house for training and experience.

Expensive consultant work: The districts feel that consultants are more expensive than in-house work. This was confirmed in a study done by the Center for Transportation Research in 2009 (Persad & Singh, 2009). CTR analyzed 1,795 TxDOT projects completed in 2006–07. Of these, 623 were done fully in-house, while 749 had a mix of consultant and in-house resources (there were no 100% consultant projects). The median fully in-house project had a $1.21 million construction value, and the percentage PE (direct plus indirect costs) was 1.28%. The median mixed PE (in-house plus consultant) project had a construction cost of $2.87 million, and 6.32% PE (direct plus indirect costs). The fact that consultants receive higher pay for the same work affects district employee morale.

Staff turnover: TxDOT suffers from a high turnover of young engineers attracted by higher wages in the private sector. Among Texas state employees, the annual turnover rate is about 20%, with about 40% of those being in the 16-to-29-years age group, followed by 18% in the 30-to-39 age group (TxDOT Workforce Plan 2009–13). TxDOT has a lower turnover rate of about 10% (Table 2.12), but the largest cohort is also in the lowest age group. The department's employee exit surveys indicate that pay is the number one motivating factor for separation of employment.

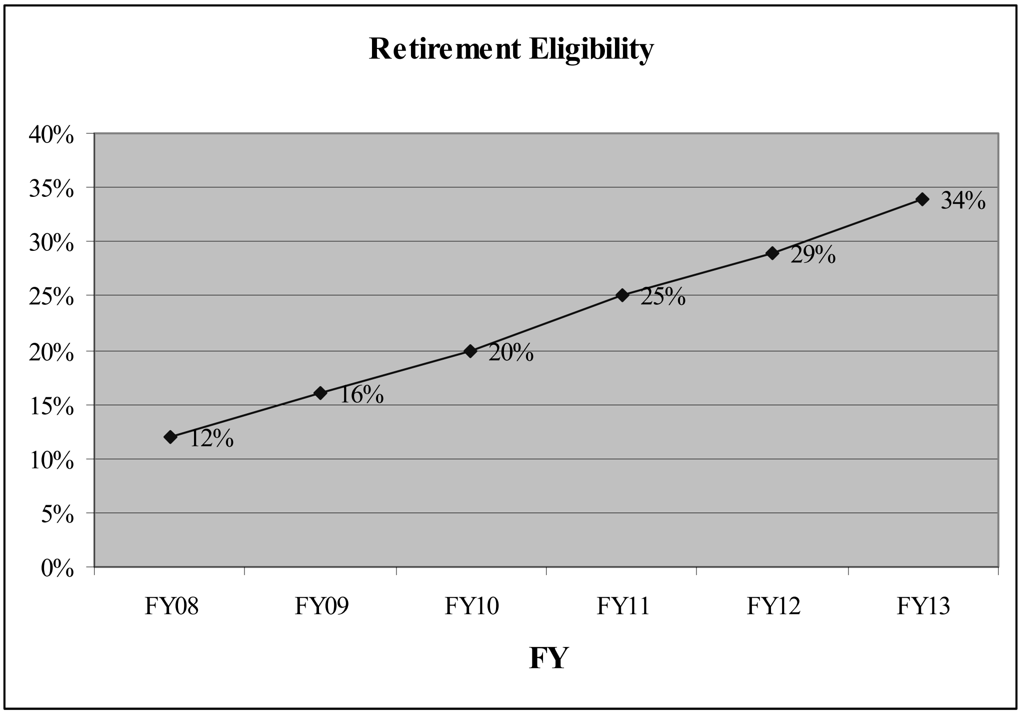
Table 2.12: Texas trend in employee turnover

Fiscal year	**2003**	**2004**	**2005**	**2006**	**2007**
State employees	18.0%	*42.0%	19.0%	18.0%	19.0%
TxDOT	11.0%	8.0%	10.0%	9.7%	10.8%

*Includes early retirement

Source: TxDOT Employee Workforce Plan

Retirement of experienced staff: Compounding the problem of employee turnover, about 70% of TxDOT managers and about 27% of all current employees are eligible for retirement in the next few years. Figure 2.11 shows the percentage of TxDOT staff eligible to retire in recent and coming years.



Source: TxDOT Employee Workforce Plan 2009-13

Figure 2.10: TxDOT staff retirement eligibility by year

By FY 2013, over 30% of department's workforce will be eligible for retirement. Table 2.13 gives the retirement eligibility percentage by staff category for the coming years. Over 50% of senior managers would be eligible. This projected retirement turnover will have an enormous impact on the department's capabilities for managing its work.

Table 2.13: Percentage of TxDOT management eligible to retire in coming years

Manager/ Work Level	FY10 or before	FY11 or before	FY12 or before	FY13 or before
Supervisor	33%	39%	44%	51%
Branch	30%	41%	48%	56%
Sec/Staff	33%	42%	51%	59%
Exec Mgr	44%	69%	70%	81%
Total	**20%**	**25%**	**29%**	**34%**

Hiring freezes: Perennial hiring freezes limit the department's ability to hire and retain qualified people. Some district managers foresee a situation like in Florida DOT, where consultants manage consultants, because TxDOT would lack the experience to do PE work and to oversee it.

2.6.9 Potential outsourcing procedure

Based on the analysis described in the foregoing sections, a potential procedure for selecting projects for outsourcing is presented here. Figure 2.12 shows a flowchart of the procedure.

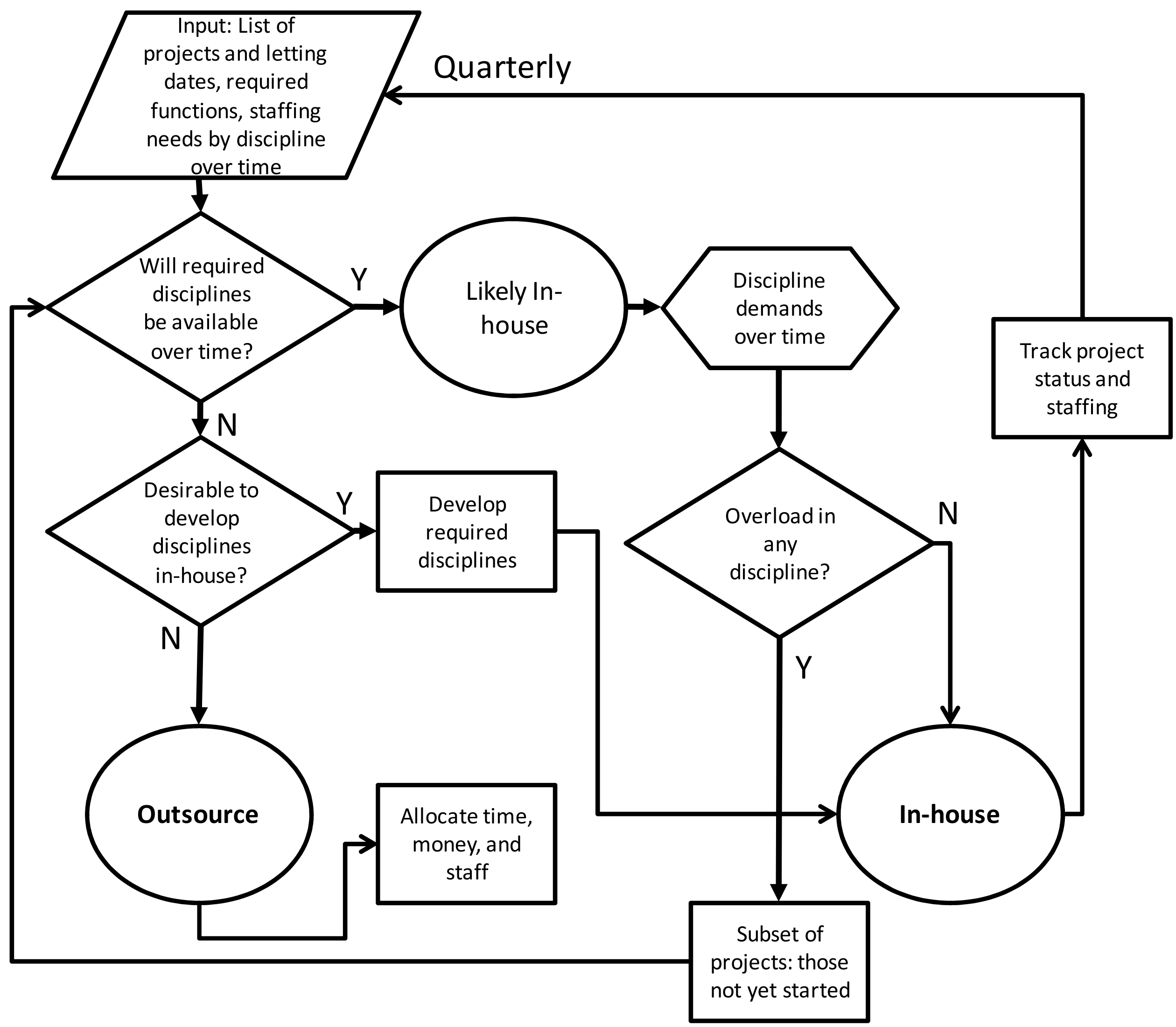


Figure 2.11: Potential procedure for selecting projects for outsourcing

The steps in the procedure are as follows:

1. Review 3–5 year letting program, using latest construction funding and letting date targets.
2. List all projects to be let, including on-going in-house work. In reality, all projects are candidates for outsourcing, but only those activities that have not yet started in-house are the real candidates. However a program resource demand analysis is needed. For each project, list the functions still to be done and target completion dates. Estimate

staffing requirements in each unfinished function in man-hours by specific engineering disciplines, on the project timeline (see referenced research reports).

3. For each project, make a determination whether the disciplines required can be found in-district or can be 'borrowed' from other districts (whether the work can be done by TxDOT). If so, mark those projects as "Likely In-house."
4. For projects where the disciplines are not available, make a determination whether it is desirable/there is sufficient time to recruit/train in-house staff. If so, mark as "In-house" and proceed to develop the required disciplines. If not, mark as "Outsource."
5. For projects marked as "Likely In-house" (i.e., work already being done in-house, plus work proposed to be done in-house), create a demand profile for at least 3 years for each discipline. If demand for any discipline is exceeded, make a sub-list of all the projects not yet started and give in-house staff 'first dibs'. Return to Step 3.
6. For projects in which in-house resource availability is not exceeded, mark as "In-house" and proceed to develop. Track project status and staffing.
7. For projects selected as "Outsource" from Step 4, allocate sufficient time and money to hire consultants and staff to manage.
8. The entire process needs to be repeated on a quarterly basis to help in identifying outsourcing candidates in good time. A team consisting of the director of TP&D, the district consultant coordinator, and the heads of design groups should be the evaluating entity.

2.6.10 Section Summary

An in-depth study of the current project delivery practices in TxDOT districts was done. It was found that districts follow different approaches for managing workload and outsourcing PE activities, with most using highly subjective methods. An analysis of the current project delivery model identified strengths, weaknesses, opportunities, and concerns. It found that there is a need for a systematic procedure for estimating staff requirements and availability at an engineering function level. Such a procedure would allow the districts to identify gaps and overloads, so they can make informed decisions on what work should be outsourced.

2.7 Recommendations

2.7.1 Section objectives

This section provides a summary of the findings of this research task, and a set of recommendations for improvements to TxDOT's project delivery model.

2.7.2 Findings

Project delivery practices of TxDOT districts were researched through a questionnaire and interviews in June–September 2009. A total of eighteen responses from metro, urban, and rural districts were compiled. Strengths, weaknesses, opportunities, and concerns regarding district project delivery practices were analyzed, and are summarized in Table 2.14.

Table 2.14: Assessment of district project delivery practices

	Positives	***Hindrances***
Internal origin	**Strengths** 1. **Skilled and experienced staff**. 2. **High morale**. 3. **Want challenges**: District managers consider the career development of in-house engineers very important. 4. **Accountability**: The districts take their responsibility as stewards of taxpayers' money very seriously. 5. **Positive attitude to consultants**: Districts welcome the use of consultants to supplement in-house staff.	**Weaknesses** 1. **Simplistic assessment of work program requirements** 2. **Qualitative assessment of in-house staff availability** 3. **Unstructured outsourcing assessment** 4. **Mandatory outsourcing**. 5. **Lack of outsourcing guidelines**. 6. **Tedious consultant selection process**. 7. **Restrictions on indefinite deliverable contracts**. 8. **Insufficient performance assessment**.
External origin	**Opportunities** 1. **Consultant market**: Consultants are available to work in all TxDOT districts. 2. **Contracting flexibility**: Districts have a choice of project specific or indefinite deliverable contracts for hiring consultants. 3. **Regionalization**: TxDOT's recent regionalization initiative will pool certain functions and resources, increasing efficiency. 4. **PDMS**: Most districts anticipate that, once implemented, PDMS will aid in decision making.	**Concerns** 1. **Resistance to change**: Most districts do not see a need to change the way they manage their work. 2. **Resources**: Managing consultants consumes district resources and impacts productivity. 3. **Expensive consultant work**: Consultants are more expensive than in-house work. 4. **Staff turnover**: TxDOT suffers from a high turnover of young engineers attracted by the private sector. 5. **Retirement of experienced staff**: 50% of TxDOT managers are eligible for retirement in the next few years. 6. **Hiring freezes**: Perennial hiring freezes limit the department's ability to hire and retain qualified people.

2.7.3 Recommendations

The districts have a number of strengths in project delivery, and there are opportunities in the current environment that are advantageous. The following recommendations address identified weaknesses of the current system and concerns in the current environment. Some are within the control of TxDOT, but others may require legislative action.

Improve work program planning

A rational approach is needed to estimate the staffing requirements over time at the functional level for district work programs. This begins with good estimation of district construction funding over at least 3 years and preferably 5 or more years, matching of projects to funding over time to establish realistic letting dates, and calculation of project staffing requirements at a functional level to meet those letting dates. The proposed Project Development

Management System (PDMS) will help with estimation of project staffing but needs benchmark standards for district performance. A concurrent study by CTR produced estimation models for man-hours at the function level for each DCIS project type (see Appendix D).

Improve project management

A planning-to-letting project team should be formed for each project to improve coordination and involve designers earlier in the process. It is imperative that districts keep track of the status of projects in order to assess staff demands/availability. Comparing in-house capability to current workload would give staff availability, which can then be aggregated for each engineering discipline. Again, PDMS will help with keeping track of current status. To be effective, it will need regular updating, at least quarterly, preferably with the direct involvement of the relevant staff, taking account of their abilities and experience, but circumscribed by performance benchmarks (see Appendix D, for example).

Create policies on outsourcing

It is important that the benefits of outsourcing are better articulated by upper management. Those benefits include ability to ramp up quickly, deliver on tight schedules, and introduce innovations. However, the rationale for mandatory 35% outsourcing in every district is not clear. In practice the number is much higher statewide, but some districts can get by with much less. A minimum of perhaps 20% outsourcing for smaller districts and a ceiling of perhaps 50% for larger districts would ensure the statewide target while satisfying individual district needs. Districts must retain some complex projects in-house for training and skill development, and career path opportunities. On the other hand, they can outsource more routine work through better planning.

Establish outsourcing guidelines

Districts need better guidelines to aid in their decision making on outsourcing. The current approach is driven by a legislative mandate, available consultant funding, and ad hoc decision making. Better estimation of program needs and in-house availability would allow staffing needs to play a larger role in the decision. Projects expected to be short of resources would be obvious candidates for outsourcing, but district training needs and long-term in-house capabilities should also be considered. The following is a suggested outline of the steps needed:

1. Review 3–5 year letting program, using latest construction funding and letting date targets.
2. List all projects to be let, including on-going in-house work. In reality, all projects are candidates for outsourcing, but only those activities that have not yet started in-house are the real candidates. However a program resource demand analysis is needed. For each project, list the functions still to be done and target completion dates. Estimate staffing requirements in each unfinished function in man-hours by specific engineering disciplines, on the project timeline (see Appendix D, for example).
3. For each project, make a determination whether the disciplines required can be found in-district or can be 'borrowed' from other districts (whether the work can be done by TxDOT). If so, mark those projects as "Likely In-house."

4. For projects where the disciplines are not available, make a determination whether it is desirable/there is sufficient time to recruit/train in-house staff. If so, mark as "In-house" and proceed to develop the required disciplines. If not, mark as "Outsource."
5. For projects marked as "Likely In-house" (i.e., work already being done in-house, plus work proposed to be done in-house), create a demand profile for at least 3 years for each discipline. If demand for any discipline is exceeded, make a sub-list of all the projects not yet started and give in-house staff 'first dibs'. Return to Step 3.
6. For projects in which in-house resource availability is not exceeded, mark as "In-house" and proceed to develop. Track project status and staffing.
7. For projects selected as "Outsource" from Step 4, allocate sufficient time and money to hire consultants and staff to manage.
8. The entire process needs to be repeated on a quarterly basis to help in identifying outsourcing candidates in good time. A team consisting of the director of TP&D, the district consultant coordinator, and the heads of design groups should be the evaluating entity.

Accelerate consultant selection process

The consultant selection process should be accelerated. The districts suggest that CCO can prequalify a pool of consultants for different kinds of work if this meets state rules. Each region can have its distinct consultant pool because certain functions require familiarity with the area. In addition, districts need more assistance with the entire process, including project scoping, negotiation, and management of consultants. Speedier contracting would allow them to outsource more routine work to consultants, further simplifying contract negotiations. Complex and unusual projects are the ones that create contracting delays, and it is precisely those that are most often given to consultants in the current reactive outsourcing mode.

The time and dollar limits on evergreen contracts should be revisited. The goal of increasing minority and disadvantaged firms is laudable, but it needs to be evaluated to see how it is working, and whether existing contracting limits are effective.

Improve performance appraisal of project delivery

The present performance appraisal system should be improved. Project-level benchmarks should be developed and used instead of the rough $5 million per designer per year figure, and productivity should be monitored at the individual and discipline level and rewarded accordingly.

Review working environment

The following recommendations relate to the working environment in the districts.

Resistance to change: As with many organizations, some TxDOT staff will resist change.. Requirements for greater transparency (e.g., posting project status online) may help.

Resources: Better project management will provide information on district staffing needs and opportunities to balance workloads. In addition, the resources required for the districts to manage consultants need to be recognized and properly tracked, because increased consultant work takes away from in-house capacity.

Expensive consultant work: The debate over consultant costs is a distraction. TxDOT needs consultants to handle overloads. A rational procedure for selecting projects for outsourcing will benefit consultants and district managers.

Staff turnover: Districts say that TxDOT is a training ground for future consultants. Until state worker compensation becomes comparable to that in the private sector, TxDOT will continue to lose trained staff.

Retirement of experienced staff: TxDOT needs to take long-term measures to recruit and retain qualified staff for management positions.

Hiring freezes: Hiring freezes can send a message that state work is not valued. They often increase the workload and stress on existing staff, which, coupled with compensation differences with the private sector, eventually drive away good workers. State policy makers need to re-consider the effects of 'doing more with less'.

2.7.4 Conclusions

A number of recommendations are presented to address the weaknesses and concerns in TxDOT's current project delivery model. These include improving work program planning, project management, and policy and procedures for outsourcing. In addition, improvements to contracting and project delivery performance appraisal are suggested, including implementation of project-level performance benchmarks. Finally, some concerns about the working environment in the districts are raised. These concerns should be addressed as the department demands better management of project delivery from the districts.

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Chapter 3. Policy Research Project Examining ARRA 2009 Stimulus Money Impacts in Texas

3.1 Introduction

Task 7: Policy Research Project examining ARRA 2009 Stimulus Money Impacts in Texas

The objective of this task was to support a two-semester Policy Research Project (PRP) at the LBJ School of Public Affairs at The University of Texas at Austin, where upwards of 12 students worked under the supervision of Leigh Boske and Rob Harrison to address different aspects of the American Recovery and Reinvestment Act (ARRA) evaluation.

3.2 Report

The Employment Impacts of Texas Department of Transportation Highway Projects funded by the American Recovery and Reinvestment Act

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3.2.1 Foreword and Acknowledgements

This report is the product of a PRP conducted at the Lyndon B. Johnson School of Public Affairs, University of Texas at Austin during the 2009/10 academic year and sponsored by TxDOT. The purpose of this research effort was to gain an understanding of how best to measure the full range of economic impacts from TxDOT 2008 ARRA-funded projects. An ARRA requirement was that direct employment on each contract be reported to TxDOT, who then forwarded the data to the U.S. Department of Transportation and others as proof of employment impacts. Data included hours of employment and total salaries. Direct impacts, however, are only part of the total impacts of ARRA support. There are impacts from those supplying products and services to the main contractor (termed “indirect”) and from the collective expenditures of both direct and indirect wage earners. The main objective of the work ultimately became the determination of the most reliable method of measuring and understanding indirect ARRA impacts.

A team of ten graduate students from diverse disciplines performed background research, engaged in interviews with key Texas contractors, wrote and edited case study drafts, and collectively highlighted key findings. As PRP Directors, Leigh Boske and Robert Harrison provided overall guidance and supervision. The PRP benefited from the contributions of a number of experts. We are especially indebted to John Barton, P.E (Assistant Executive Director, TxDOT), who acted as the TxDOT liaison with TxDOT and advised us several times during the study. Al Alonzi, Deputy Assistant Division Administrator (FHWA-Texas Division), also provided support and encouragement. Ken Barnett, P.E (Construction Section Director, TxDOT) headed the team collecting and reporting the ARRA direct impacts and met with the class to provide an insight into ARRA reporting requirements. Dr. Khali Persad (CTR) also assisted the class on the issue of direct benefits, based on work he is currently undertaking on that topic. Early speakers on the course included Mark Marek, P.E (Director Design Division) and Dr. Isabel Victoria (Wilbur Smith Associates), who provided insights into the TxDOT planning process and induced impact modeling, respectively.

The method chosen by the team to measure indirect impacts required a champion to make it work and Tom Johnson, P.E., President of Texas Chapter of the Association of General Contractors (Tx-AGC), stepped up to fill that role. He asked Thomas Bohuslav, P.E (Consultant to the Tx-AGC) to select key AGC members representing a wide variety of highway construction suppliers and contractors to help the team. The data on supply chains in this report is based on interviews with Tx-AGC members who were willing to discuss their core business, the suppliers with whom they worked and finally ARRA impacts. These individuals made the study a success and, though they remain anonymous, we are indebted to their cooperation and frankness. The study outline could not have been completed without their support but team alone accepts responsibility for the contents of the report.

3.2.2 Executive Summary

Our study results indicate the employment impacts of ARRA on the road construction and maintenance industry in Texas have been positive. While our surveys found no direct hiring as a result of ARRA spending, the legislation had a measurable employment retention effect on almost every company interviewed. Beyond employment impacts, infrastructure and transportation investments contribute to the productivity of the economy in the long-run.

This chapter report is organized as follows:

1.) Summary of interviews with contractors reporting direct-jobs associated with mobility and preservation projects.

2.) Summary of interviews with select non-reporting, but impacted subcontractors and material suppliers in the road construction and maintenance industry.

3.) Copy of presentation of summary findings and speaking notes.

Our research addressed the job impacts of the $2.25 billion ARRA stimulus spending on transportation projects in Texas. Interviewees generally confirmed the accuracy of the ARRA jobs reporting, but the researchers quickly learned the importance of work hours and overtime in road construction. Most companies interviewed were in a state of distress with commercial business down, and TxDOT work not able to make up the difference.

When their workforce is underemployed, companies generally choose to "absorb" new ARRA contract hours using existing skilled and semiskilled workers. Therefore, new hours generated as a result of ARRA-funded projects typically have not created new jobs. All contractors reported increased competition for public-sector project bids. We found traditional modeling techniques to be inadequate for our purposes primarily because they do not address the way that contractors behave in economic downturns.

With the assistance of the Associated General Contractors (AGC), representatives of the hot-mix asphalt, asphalt emulsions, pre-stressed concrete, site preparation and excavation, and trucking sectors were interviewed to analyze each firm's production process, employment structure, and business model. Companies ranged in size from 28 employees to over 350. The consensus was that suppliers are aware and responsive to fluctuating business conditions. Their success relies upon the recovery of private-sector spending, but in some cases their survival at current employment levels is dependent on TxDOT projects in general, and ARRA funding in particular. They cannot distinguish whether a project is funded by state or ARRA money, but are sensitive to changes in overall volume. We became aware that ARRA funding in many cases ensured the survival of firms, but it was by no means a pre-condition for job creation. In the words of one contractor, "ARRA may not have created new jobs, but they did save an industry."

3.3 Introduction

Highways and public roads are the backbone of transportation in the United States. In Texas, there are more 300,000 miles of highways and public roads supporting over 24 million residents and one of the largest economies in the U.S. (U.S. Census Bureau, Population Division December 2009).

On February 13, 2009, in response to the deepening economic recession, Congress passed the American Recovery and Reinvestment Act. An immediate goal of ARRA was to retain existing jobs and create new jobs while fostering economic stabilization. This historic act provided $787 billion in total funding; TxDOT received $2.25 billion of the almost $26 billion that was allocated to transportation construction nationwide.

The ARRA stimulus funds allowed TxDOT to increase letting of contracts for projects already cleared for construction or "shovel ready." There are over 900 companies in Texas that regularly bid for or contribute to the contractors that bid these projects.

3.4 Methodology

One common way that analysts quantify the economic impact of a transportation investment is to estimate the number of jobs associated with the project's expenses. Impacts are classified into three categories to identify the effect that project expenditures have upon employment in different sectors of the economy. These categories are direct, indirect, and induced effects. Direct employment refers to the jobs associated with the main construction activities that lead to the completion of the investment. Indirect employment comprises those jobs associated with the production of various supplies and materials used in project construction, or one tier removed.

Last, the expenditures of individuals employed directly or indirectly on projects comprise induced impacts. Combined, these three categories track effects outwardly much like ripples from a pebble dropped in a pond. The total direct, indirect, and induced impacts generated by direct construction expenses for the transportation investment are often referred to as the project's multiplier effect. Generally, multipliers are higher for larger regions with more diversified economies and lower for smaller regions with more limited economic development. They also tend to be smaller during economic downturns.

ARRA contains provisions that are designed to quantify the direct employment impact of investments through mandatory reporting. Section 1512 requires fund recipients to report on a monthly basis the number of jobs associated with any project that is financed with ARRA money along with the number of hours contributed by each worker (http://www.dot.gov/recovery/docs/section1512jobsreporting.htm). Yet, fund recipients are not required to estimate indirect or induced employment impacts; thus, the full impact of highway construction projects upon employment in the Texas economy is not captured in ARRA-reported figures.

A widely used approach in determining employment impacts is through the use of models that rely upon input-output (I-O) analysis. Such I-O models typically utilize information from input-output tables constructed and maintained by the Bureau of Economic Analysis, wage, and employment surveys administered by the Bureau of Labor Statistics, Census Bureau demographics and spending data. However, the estimation techniques of these models are not typically transparent, rely too heavily upon generally accepted growth trends that may not be accurate, and can yield vague results. As observed repeatedly in this study, firms tend to adjust the work-week hours of existing employees before hiring new workers, and the study group could not determine how models account for this phenomenon. Moreover, the models potentially may use data that do not necessarily reflect the current economic situation. For example, the Bureau of Economic Analysis' Input-Output Data have not been updated since the recent economic downturn (http://www.bea.gov/industry/io_benchmark.htm).

Our study's initial approach was to measure the indirect employment impact of ARRA highway investments by gathering data directly from suppliers and subcontractors associated with specific projects rather than relying upon the more aggregated county-level and state-level data. We piloted this methodology with two case studies. A key reporting liaison at TxDOT selected two ARRA projects. They comprised the two major categories of TxDOT highway construction work funded through the ARRA: mobility and preservation. Each research group was provided with material source information reports, which list the names of firms that provided materials for a particular project, and direct employment reports. The goals of the initial case studies were to confirm the accuracy of the direct employment data reported by prime contractors to TxDOT and to gauge the indirect employment impact associated with each project. Two survey questionnaires were developed, one for prime contractors and one for suppliers and subcontractors. Each research group conducted face-to-face interviews with the prime contractors, and distributed the questionnaires for the suppliers and subcontractors by mail.

We were able to verify that the direct employment data submitted to TxDOT by prime contractors was accurate and in some cases gather information about the employment associated with the prime contractor's construction activities that did not necessarily take place on the job site. However, the response rate from suppliers and subcontractors was poor and presented a flaw in our initial methodology (for example, jobs associated with payroll preparation, scheduling, purchasing, and cost estimation). The questions developed for the supplier and subcontractor survey asked businesses to estimate the number of jobs created or retained by the ARRA project for which they provided materials. The ARRA project may not have necessarily comprised a large portion of the supplier or subcontractor's annual business revenues; moreover, these firms were not always aware of the source of funds.

After identifying limitations of the initial approach, the group devised an alternative. Rather than viewing specific suppliers as indirect beneficiaries of ARRA funds, we attempted to gather data about the employment decisions of suppliers through comprehensive interviews. With the assistance of the AGC, five firms volunteered to represent the major categories of suppliers utilized by the highway construction and maintenance sector.

Interviewees were asked to describe their specific supply chain from inputs to jobsites and discuss how they adjusted their employment needs as business activity fluctuated. This approach yielded more detailed information about actual practices than models were capable of capturing.

3.5 Preservation Case Study

3.5.1 Background

This case study focused on a preservation job on US 77 outside of Austin.

Contractor: Name Omitted for Anonymity, Austin area
Award Amount: $1,000,000
Work Begun: Summer 2009
Scope of Work: Resurface
Direct Employees: 165
Direct Hours: 6593
Direct Payroll $: 108,617

This job was chosen as a "typical" preservation job that involves the resurfacing a stretch of road. Preservation jobs were an important part of the focus of ARRA funding because of the short turnaround time to get the projects started, money spent, and people employed.

3.5.2 Main Contractor Interview

The interview with the prime contractor served several purposes beyond the general information about the job—to assess the accuracy and details of the direct job numbers associated with the contract, to enhance and clarify the supply chain, to determine the representative nature of this single job in order to establish potential for extrapolation, and to gain insight on the potential induced impacts generated by the employees.

3.5.3 Direct Jobs

The first issue addressed was the direct job impacts—the data reported by ARRA recipients reflecting work performed on the job site. The contractor emphasized that the procedures for counting direct jobs on site as part of meeting the requirements for the ARRA funding were very rigorous; consequently the 165 direct employees reported for this job is an accurate representation of the employees working on the site. In addition, the contractor stated that it had the same crew work the entire duration of this job, thus minimizing the chance of "double counting" a single job function. Further, the contractor elaborated on the allotment of overtime hours; this job reflected a typical overtime scenario of 10% of the payroll. Overtime is not a method to reduce employees needed for the job, but rather a reflection of the time of year and conditions of the work. In all, this particular preservation job seemed to reflect an accurate count of direct employees on site with little room for distortion.

Another potentially important aspect of direct jobs is the prime contractor's overhead employment allocated to this particular job. In this case, the contractor emphasized the point that allocation of overhead employment on a per job basis is not possible for their company; they rely on a "core" group of overhead staff that adapts to different jobs and do not only work on a single job. The contractor would not provide an estimated percentage of overhead as part of overall project costs, and thus overhead employment could not be derived on a payroll basis. However, the contractor did state that its overhead is kept at a minimum to provide a competitive advantage, and that the recent recession has not impacted this staff. Overhead jobs were likely not impacted by this single preservation job based on this information from the contractor.

Finally, the contractor noted that no employees were hired locally for the job; thus, the direct job impacts can be attributed to the company's home area, in and around Austin, Texas.

3.5.4 Supply Chain

The contractor was also questioned on the basic supply chain developed from the TxDOT bid documents. In this case, the main contractor also owned the major supplier of aggregate and hot mix. The contractor stated that a job of this size ($1,000,000) would have very little overall impact on suppliers, and would not produce a notable job impact. The only other major supplier identified was the asphalt supplier, a very large refining company that would also likely not be able to disaggregate this specific job from its overall production. This highlighted once again that the idea of disaggregating job impacts on a project by project basis is unrealistic—aggregate impacts must be considered to see the impacts on contractors and, even more so, suppliers.

The contractor also stated that, for this job, no supplies were purchased in the locality of the job; thus any potential supply chain (indirect or induced) impacts would not be attributed to the particular area.

3.5.5 Extrapolation

One hope of this study was that this preservation job might be representative in many ways to allow for potential inferences about the overall impact of this project category. The contractor confirmed that this job was a typical preservation job. However, this particular category of job as a whole had increased as a portion of their overall work in light of the ARRA funding. The contractor also stated that the aggregate impact of all 15 ARRA jobs awarded to their company had likely allowed them to "save a crew" of employees. In addition, the company had maintained a steady level of employment through 2009. Thus, the single ARRA project does not necessarily lend itself to extrapolation, because the individual impacts are difficult to disaggregate. Rather, aggregating the projects does begin to show potential impacts and patterns in personnel decisions.

3.5.6 Potential Induced Impacts

As discussed above, neither direct employees nor supplies were obtained locally to the project; thus, any induced impacts from spending by the direct or indirect employees of the project would have been in and around Austin and the various small suppliers for the project.

3.5.7 Supplier/Subcontractor Interviews

No supplier or subcontractor interviews were performed. As mentioned, the project itself was very small relative to the overall revenue stream of the companies involved and the type of work involved very few suppliers and contractors. The main contractor in this case expressed that indirect job impacts would be negligible for this particular project; the asphalt supplier was not contacted for this reason.

3.5.8 Conclusions/Path Forward

The interview for this case study led to several important conclusions. First, the single project approach to a case study was not appropriate in assessing job impacts. Even though direct jobs are counted for each project, individual projects are part of a large aggregate of jobs by which contractors make their personnel and financial decisions. Therefore, in order to make any statements about job impacts, the ARRA funds must be considered on an aggregate level. In this case, the contractor believed that jobs were saved by the aggregate of ARRA projects—this jobs-saved number is much more valuable than any direct job count number of employees on-site.

Secondly, aggregate impacts are even more important to derive information from the supply chain—as the overall money awarded to the project spreads through the supply chain, the impact becomes smaller and smaller as would be intuitively expected. Thus, suppliers would be highly unlikely to have any disaggregated information about their revenues in relation to employment. In the case of suppliers, the entire ARRA impact may even be difficult to disaggregate.

Finally, this contractor highlighted the importance of each company's business model on the ultimate employment impacts of any stimulus or downturn. By having an integrated model with a core group of people, this contractor was able to maintain employment throughout the downturn. In any future work, the business structure or model must also be understood as an important factor in job impacts.

3.6 Case Study Addendum: A Supplier's Perspective

3.6.1 Introduction

The initial case study surrounding the preservation project in the Austin, Texas area provided insight crucial to understanding the impacts of the ARRA funding from a prime contractor's perspective. The second case study involved interviewing the major supplier for the preservation job in question.

3.6.2 Background

This case study focused on a preservation job in the Austin area.

Contractor: Name Omitted for Anonymity
Main Supplier: Name Omitted for Anonymity, Austin, TX
Contract Amount: $1,000,000
Work Begun: Summer 2009
Scope of Work: Resurface
Direct Employees: 104
Direct Hours: 7,110
Direct Payroll: $113,637

Similar to the initial project studied, this preservation job was quick in mobilization and brief in duration.

3.6.3 Main Supplier Interview

The interview with the main supplier was crucial in realizing one of the initial goals in the overall case study: "following the money" to assess any indirect employment impacts. In this case, the main supplier provided asphalt to the prime contractor; the costs associated with the asphalt were a substantial amount of the job's total budget. The supplier did not hire any additional employees for this project. This is partly explained by the high level of automation associated with the supplier's business model. However this project, coupled with another contracted ARRA job, helped to delay employee layoffs for several months by this supplier.

3.6.4 Other Supplier Interviews

To this date, no other supplier interviews have been performed.

3.6.5 Potential Induced Impacts

As discussed above, neither indirect employees nor major supplies for the project (other than the rock provided by the main supplier itself) were obtained locally to the project; thus any induced impacts from spending by indirect employees of the project would have been in and around the Austin area and the various small suppliers for the project.

3.6.6 Conclusions/Path Forward

The interviewees for this case study reiterated the previous conclusion drawn by the initial case study that the individual project approach was not appropriate in assessing job impacts. In this case, the supplier interviewed believed that job losses were minimized and delayed by many months due to the aggregate of the company's ARRA projects. As in the previous case study, this supplier benefited by having a business model built around a core group of people. This company's business model includes a system of high automation and low labor costs, allowing the supplier to minimize job loss throughout the downturn. In any future attempts in assessing job impacts, business modes must be taken into account.

3.7 Mobility Case Study

This case study focused on a mobility job.

Contractor: Name Omitted for Anonymity
Award Amount: $7,000,000
Work Begun: Summer 2009
Scope of Work: Widen roadway
Direct Employees: 23 (as of January 2010)
Direct Hours: 1000 (as of January 2010)
Direct Payroll: $21,243.74 (as of January 2010)

3.7.1 Project Background

The winning bid for this project came in 50% below the Texas Department of Transportation estimate. In typical years, having contractors bid so far under the estimate would be very unusual. To date, Texas has awarded more than 90% of their ARRA highway contracts below TxDOT estimates (http://www.reuters.com/article/idUSTRE6184X920100209). However, according to this contractor and others, the overall numbers of projects per firm at the beginning of 2009 were at critical lows across the board. Firms typically have a number of projects under way, as well as several in the pipeline. By doing so, the company is able to schedule work for a period of time and is able to budget for workers, equipment, and overhead. Without the promise of work to come, firms reduce their activity to meet coming work demand and on this particular project, the contractor would have had to let go approximately 20 workers.

The project broke ground in summer 2009 and is scheduled for completion in the summer of 2010. The total project duration is approximately 14 months. This project is designed in two major phases. First, brand new eastbound lanes will be constructed. Then, traffic will be shifted onto these new lanes while the existing westbound lanes are re-built.

The project follows a typical road construction process with 800- to 2500-foot long sections of roadway at a time under construction. First excavation and earthwork, then the addition of the subgrade, followed by the concrete base, flex-base, then asphalt sealcoat with curing times between each phase. Each section takes approximately a month with finishing touches like striping, railing, and signage at the end. Drainage and bridge structure sections are added as needed, but have their own construction phases. For example, the eastbound bridge deck structure for this project took approximately 4 months: 2 months for earthwork and shaft drilling/construction followed by 2 months of pre-stressed concrete work for the decks. The bridge sections were approximately one thousand feet in length.

3.7.2 Direct Job Impacts

The major activities of the mobility project include clearing the right-of-ways, reclaiming old pavement material, laying down foundations and base coats for new lanes, paving, signage, and transporting materials to and from the site. It also requires earth movement for embankment construction and structures for two new bridge sections. The project cost is estimated to comprise of 60% material and subcontractor work, while 40% accounts for labor, overhead, and profit.

From the perspective of the prime contractor, the direct job impacts of this stimulus-funded project have been beneficial. As noted above, approximately 20 jobs with the prime contractor were saved as a result of being awarded this project. In addition, for the months of December, January, and February the prime contractor has reported on its ARRA Monthly Employment Report (form FHWA-1589) that this stimulus-funded project has paid for over 7,500 hours worth of labor with a payroll of almost $200,000. This report counts the man hours of both its contractors and the on-site subcontractors. Most of the workers employed by the prime contractor live and work locally, within a 60 to 10 mile radius of this project's location. That is, their crews typically live and work in the same regions.

Feedback from subcontractors also indicates that this project helped retain workers. For example, one subcontractor is a disadvantaged business enterprise (DBE) that also received work from the ARRA-funded project. According to a company representative, the company was in the process of laying off workers because of a decline in awarded bids. For example, they secured 24 bids in 2007, but only 13 in 2008. As a result of this drop, finances had become extremely tight for the company, and it downsized from 8 to 3 employees. However, the number of secured bids increased to 24 in 2009, with exactly half representing stimulus-funded projects. Feedback from DBEs also suggests that the number of secured projects has decreased resulting in extremely tight financial conditions.

3.7.3 Indirect Impacts

As a condition of the ARRA, the prime contractor as well as its subcontractors must report monthly the hours of all employees who worked on the construction site. This information is submitted to the Federal Highway Administration, the Office of Management and Budget, and to the Chair of the House of Representatives Transportation Committee's Office. These numbers give a reliable estimate of the labor associated with the construction activities on the project site. However, in order to capture a more elaborate picture of the employment impact generated by this project, we also attempted to gather information about the labor associated with activities in support of the project that took place off the construction site, which we describe as *indirect* employment.

As described in the methodology section in this paper, we sent out surveys to all the major suppliers and subcontractors for this particular project in order to collect indirect job numbers. Survey response rates for distributed surveys were extremely low, which caused us to change course and interview suppliers and subcontractors on a case-by-case basis in order to better understand each industry's business model.

The prime contractor also produces some of the materials it uses in highway construction on site. For example, the firm estimated that it employs three people at its hot-mix plant, and four to five people in a laboratory to test the product.

3.7.4 Job Estimates/Key Findings

While the positive effects of safer roads cannot be adequately quantified in terms of simple dollars, the result of this stimulus project has resulted in tractable employment for this particular contractor. Though this contractor was not able to hire new employees due to being awarded the project, it is clear that without this project their business cycle would have been impaired, leading to layoffs. This is one small example of what appears to be the trend with ARRA projects. In general for the third quarter of 2009, business growth overall would have been anywhere from 1.2 to 3.2% less without the stimulus (Congressional Budget Office, 2009).

When analyzing the difference between TxDOT estimates and contractor bids, it appears as though contractors are bidding as close to "at-cost" as possible, which reduces the amount of capital that can be reinvested in the firm for both new machinery and increased employment.

In order to get a better idea of how highway-related expenditures flow from prime contractors to the industry for construction materials, we developed a supply chain diagram. The highway-related expenditures sustain employment for the direct contractor, but also generate revenue for each of the project contractor's particular suppliers and subcontractors. Likewise, these funds will trickle down to the firms that provide inputs for the supplier's product. The money spent on projects such as these also flow through to the surrounding communities where workers reside. The wages earned by residents eventually support businesses of all types and provide the basis for taxes that fund government services at the local, state, and national level.

3.8 Supply Chains

In realizing the attempts to disaggregate both direct and indirect job impacts associated with a single ARRA-funded project were inadequate, we widened our scope of investigation to allow for a more comprehensive, aggregate approach. Our intent was to interview several different contractors in an attempt to understand their overall business operations; in particular we were interested in the company's employment practices, their business model (including their major costs, sources of revenue and any recent adjustments due to the economic downturn), and the overall impacts ARRA has had on their business.

With the help of Mr. Thomas Bohuslav, consultant for the AGC of Texas, four companies involved in the state's highway construction and maintenance industry were initially selected to be interviewed. The companies interviewed represent the following industrial segments: hot mix asphalt, asphalt emulsion, pre-stressed concrete beams, and excavation/site preparation. The initial interviews underscored the importance of transportation as a major cost for these firms; therefore, a fifth company−a trucking firm−was also interviewed.

Figure 3.1 displays a diagram of the supply chain for the mobility case study; Figure 3.2 shows a typical supply chain for a hot mix asphalt plant.

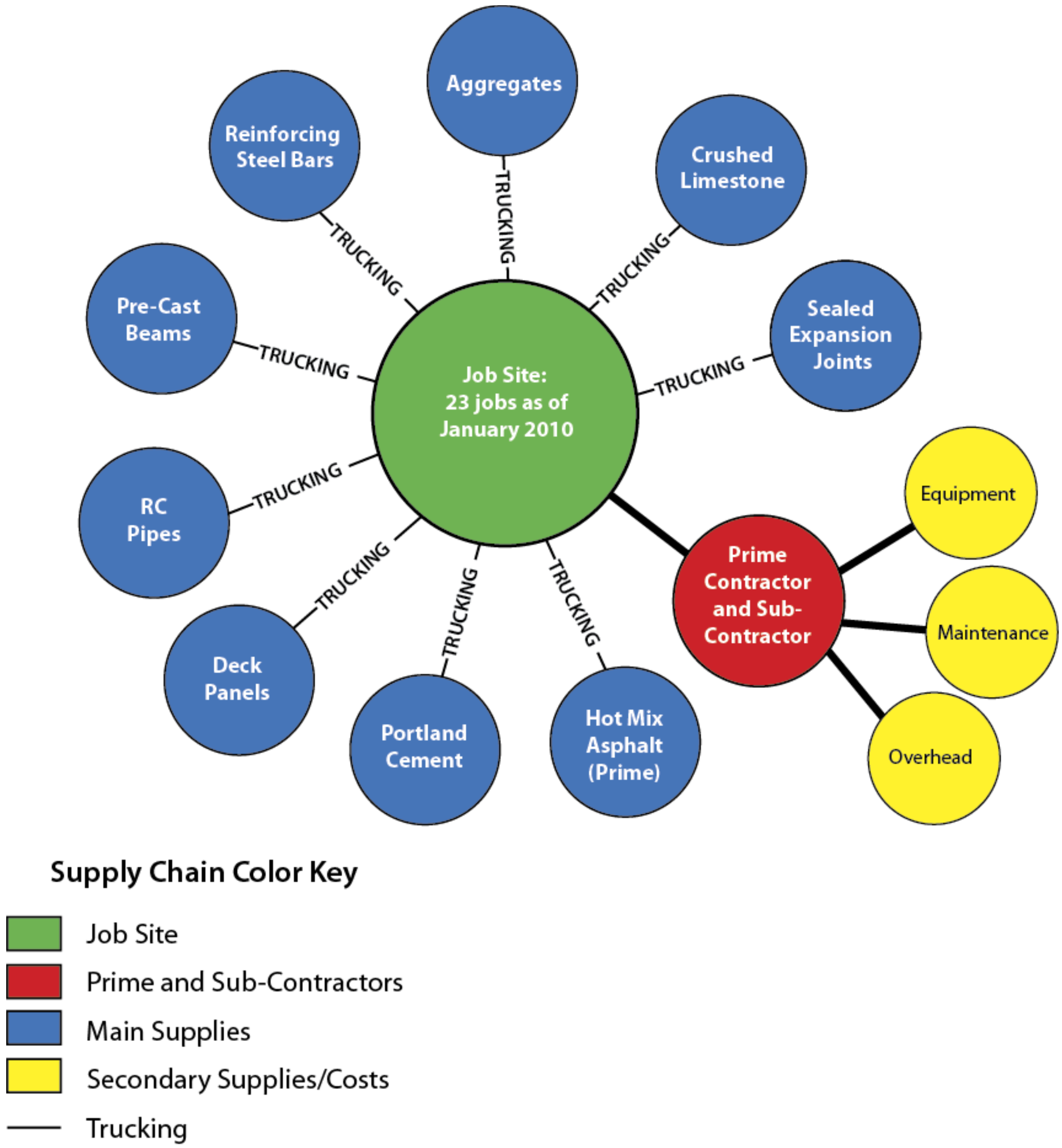


Figure 3.1: Supply chain for the mobility case study

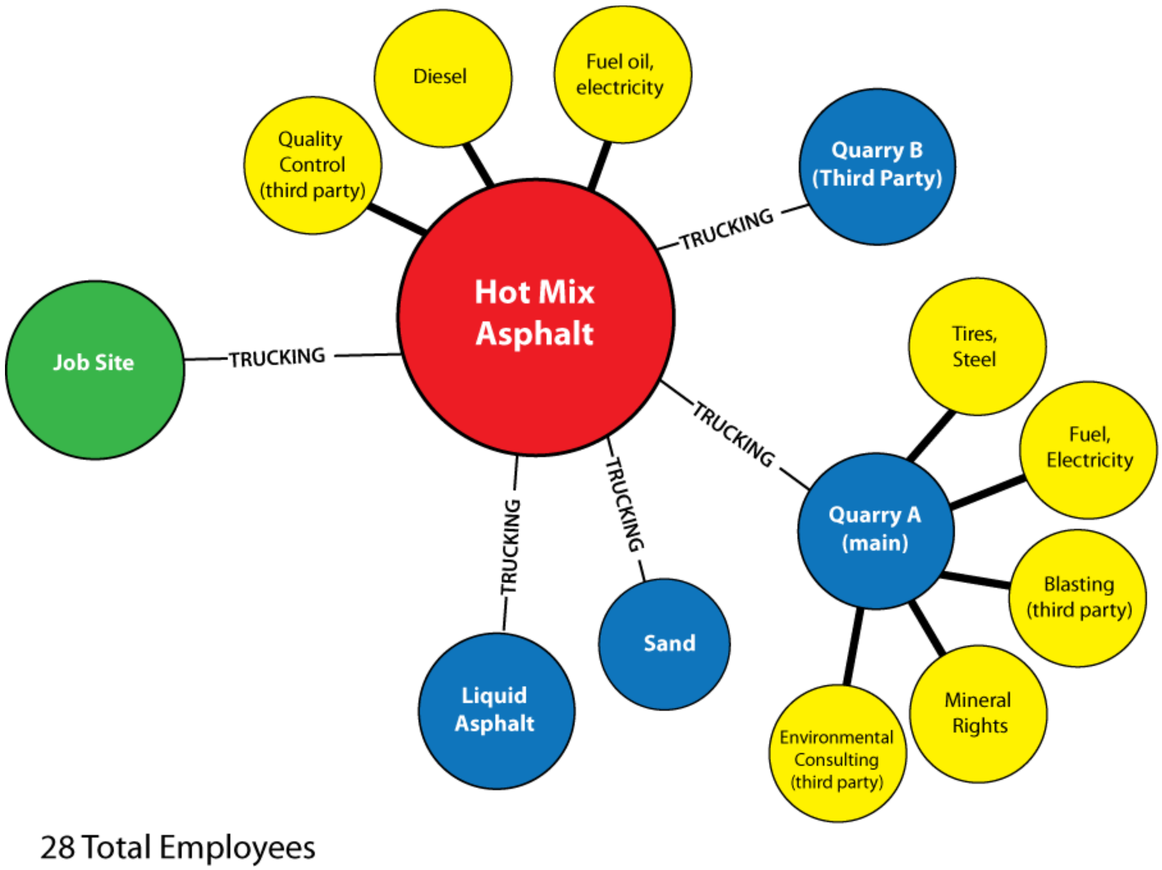


Figure 3.2: Typical supply chain for a hot mix asphalt plant

3.9 Hot Mix Asphalt Interview

3.9.1 Company Structure: Hot-Mix Asphalt Supplier

The company interviewed as a representative of the hot mix asphalt industry began operations in the mid 1990s. It supplies asphalt to contractors and sub-contractors in the public and private construction industry. The business currently operates two asphalt plants. These plants run continuously, and have a maximum output of 400 tons per hour.

3.9.2 Process

A general and simplified overview of the hot mix production process begins at the quarry. At the quarry site, a third-party blasting company is brought in every few weeks to use explosives to forcefully remove limestone from the ground. The rock is then crushed, sorted and stockpiled on site; the company employs third-party trucks to transport the rock to the asphalt plants.

At the asphalt plant, the crushed rock from the quarry is blended with sand, which is supplied third party, to make the asphalt aggregate that comprises over ninety percent of the final hot mix product. The last major component of the hot mix is the liquid asphalt, which is again supplied by a third party and represents approximately 5% of the final product. Together, all of these inputs (crushed rock, sand, and liquid asphalt) are heated and mixed together to form hot mix asphalt. The final product is tested daily for quality control by both in-house staff and a third party engineer.

3.9.3 Employment Structure/Practices

The quarry and asphalt plant operations are highly automated processes for this company, limiting the overall need for manpower. In total, 28 employees work among all three job sites, including all management/owners. Each asphalt plant has a plant operator, quality control technician, and ground labor.

All employees, with the exception of upper management, are hourly workers who typically are scheduled 40-hour workweeks, plus overtime; upper management are salaried employees. In addition, the 24 hour a day operations of the asphalt plant requires plant workers to be distributed into shifts; the role of overtime and the shift structure is ultimately determined by demand for hot mix.

3.9.4 Business Model

A company's business model can be reflected in its cost and revenue structure. In the case of the hot mix asphalt company, analyzing these structures provided insights regarding the impact of changes in demand for their product (whether by economic downturn or stimulus funds). The following is not a complete analysis of this company's business model and operations, but rather the key points highlighted by the owner.

3.9.5 Costs

As previously discussed, this company relies heavily on automation; therefore the labor costs are a relatively small percentage of the company's overall costs−approximately 10%. However, the labor that is in place is considered a "core" group that is critical to operations and every effort is made to retain staff by reducing hours over a wide range of work week hours.

For example, when demand is high, the company will pay its employees 25 to 30 hours of overtime before choosing to hire a new shift of employees. Conversely, when sales are down, the employer will take several measures to delay lay-offs, including cutting weekend work and reducing weekday hours. Retaining these core employees is key to the business model, as many of these employees, particularly the skilled laborers, are difficult to replace. When changes in employment must be made, the unskilled laborers are affected first. Finally, in addition to the company's own employees, local subcontractors are hired to provide blasting services, conduct the environmental reporting, and assist in quality control testing. These third-party employees are also very sensitive to changes in operations at the asphalt plant and quarry.

Operating costs associated with this business include sand, liquid asphalt, fuel, and electricity purchased from external suppliers, as well as payment for mineral rights to the quarry's landowner. Heavy automation leads to major costs associated with repairing machinery and overall maintenance of the plants and quarry (the company has an inhouse mechanic that performs most of the repairs). Maintenance also requires the purchase of supplies such as tires and steel from external suppliers.

A major cost specifically highlighted by the owner is trucking; all trucking is provided by a third-party subcontractor and accounts for 25 to 35% of the sales. Trucks are used in several phases of the business operations, including transporting rock from the quarry to the asphalt plant, transporting other supplies (liquid asphalt, sand) from the supplier to the asphalt plant, and, finally, transporting the final hot mix product to the job site. Though the company can store liquid asphalt for 2 to 3 days and store rock at the quarry, trucking is essentially a daily operation for the business.

Most of the remaining costs associated with this business come from supplies. While this company usually supplies its own limestone rock, it does rely on a third-party quarry from time to time when other types of crushed rock are needed. Other major categories of supplies include sand and liquid asphalt.

3.9.6 Revenue

In terms of its sales, this company, like many construction companies, had to shift its business model to accommodate the decline in the commercial market. Private work consists mainly of paving corporate and residential sites and selling rocks for non-road work. Without sales in residential and corporate construction, the company had to increase its business with public entities. Consequently, their business model shifted from 75% public/25% private, historically, to 90% public/10% private.

3.10 Asphalt Emulsion Interview

3.10.1 Company Structure: Asphalt Emulsions Supplier

The company interviewed as a representative of the asphalt emulsion industry has multiple facilities throughout the state of Texas. The basic supply chain, as provided by our asphalt emulsion participant, has four key inputs: wood pulp, water, emulsifying agent and liquid asphalt (Figure 3.3). The four main inputs mainly rely on the use of third-party trucking firms for transportation of the raw materials; wood pulp is sometimes brought in by rail. Third party trucking firms are also used to transport the finished asphalt emulsion product to the work site.

Asphalt emulsions are primarily used in preventative maintenance preservation projects. Approximately 95% of the participant firm's total product is sold to TxDOT, cities, counties, and contractors for use in the preventative maintenance of road pavement. Approximately 90% of this share goes towards public roads at the city, county, and state level. The supplier prefers to supply worksites that are within a two-hour distance of one of their plants.

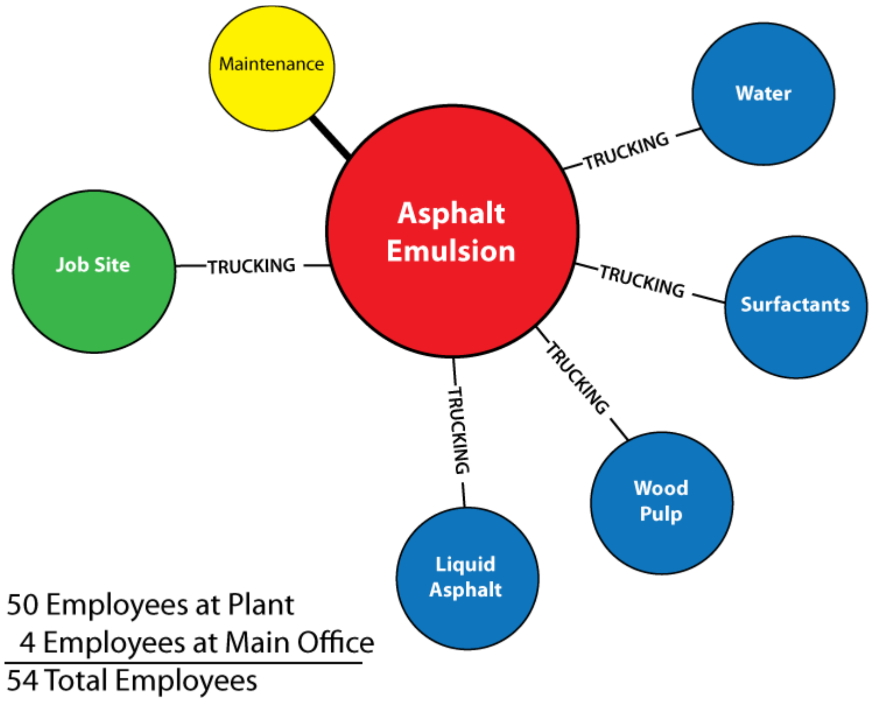


Figure 3.3: Typical supply chain for an asphalt emulsion operation

3.10.2 Process

Asphalt emulsion is produced by a combination of the four input materials: water, liquid asphalt, emulsifying agent and wood pulp. The final product will range in consistency based on the composition of the formula. Typically wood pulp will make up (1.0–2.0%) of the product, surface-active agent (0.5–3.0%), water (25.0–30.0%), and liquid asphalt will make up the remaining portion (usually around 70%).

3.10.3 Employment Structure/Practices

On average, each plant employs five full-time employees who are responsible for overseeing the asphalt emulsion manufacturing process as well as quality control. A few employees divide their time between several plants. The firm's staff not involved in production is responsible for technical services, marketing, operational management, plant operations, and payroll.

Approximately four people work in the supplier's headquarters office. Two are responsible for sales and one is responsible for safety and environmental concerns. The Texas headquarters office also receives support from national headquarters staff. Several of its staff members are responsible for the purchasing of plant equipment and accounting of the Texan facilities.

An outside firm does repair and maintenance of plant equipment. Plant staff generally performs "yard-keeping" tasks, i.e., cleaning up spilt asphalt. Maintenance is approximately 15% of total production costs.

Generally, plants operate from 6 a.m. to 6 p.m. six days a week. In slow periods, one to two crews is scheduled each week, but when business ramps up, three to four crews are scheduled. At full capacity, asphalt emulsion production facilities are running 24 hours per day.

The number of people on a shift varies between two and four. During busy periods plants have up to ten full-time employees. If crews are working 72 hours a week and are at capacity, the firm will consider hiring more employees.

3.10.4 Business Model

A company's business model can be reflected in its cost and revenue structure. In the case of the asphalt emulsion firm, analyzing these structures did not provide as much insight as the interviews conducted with the other four suppliers (more on this particular topic will be discussed below). The following is not a complete analysis of this company's business model and operations, but it is a summary of key points found throughout the course of the interview.

3.10.5 Costs

Labor and operations comprise approximately 15% of total costs. This demonstrates the heavy mechanization present in the production of asphalt emulsions. Much of the labor used in production is highly specialized. It is expensive to hire new employees and pay for training; therefore the firm is more likely to increase or decrease shift hours based on demand fluctuations in the market. To date, the firm has yet to let any employees go. However, if output measures were to fall below allotted tonnage per year for a sustained period of time, the supplier would consider letting people go.

Similar to the hot mix asphalt firm, a major cost in asphalt emulsion production is transportation of goods, which is primarily conducted via trucks. A third-party subcontractor provides all trucking services. This expense accounts for approximately 20% of total costs. As stated earlier in the study, trucks are used to transport both input materials to production facilities and finished products to the final work site.

The rest of the firm's expenses are comprised of third-party maintenance and supply costs. Supplies are the largest component of the firm's total expense and are also the most variable cost due to fluctuating prices in the liquid asphalt market.

3.10.6 Revenue

This firm has experienced a drop in overall business. Because the majority of this firm's work was public before the recession, there was no major shift from privately to publicly funded projects.

3.11 Pre-Stressed Concrete Beams Interview

3.11.1 Company Structure: Pre-Stressed Concrete Beam Supplier

The company interviewed is representative of the pre-stressed concrete industry in Texas, including its processes, business model, and employment structure. However, this company works almost exclusively on TxDOT projects (very few commercial projects) as the owner prefers the detailed specifications that accompany government work. This company has two locations in Texas. Their locations are determined by their proximity to job sites and their suppliers. Figure 3.4 illustrates the supply chain for a typical concrete beam supplier.

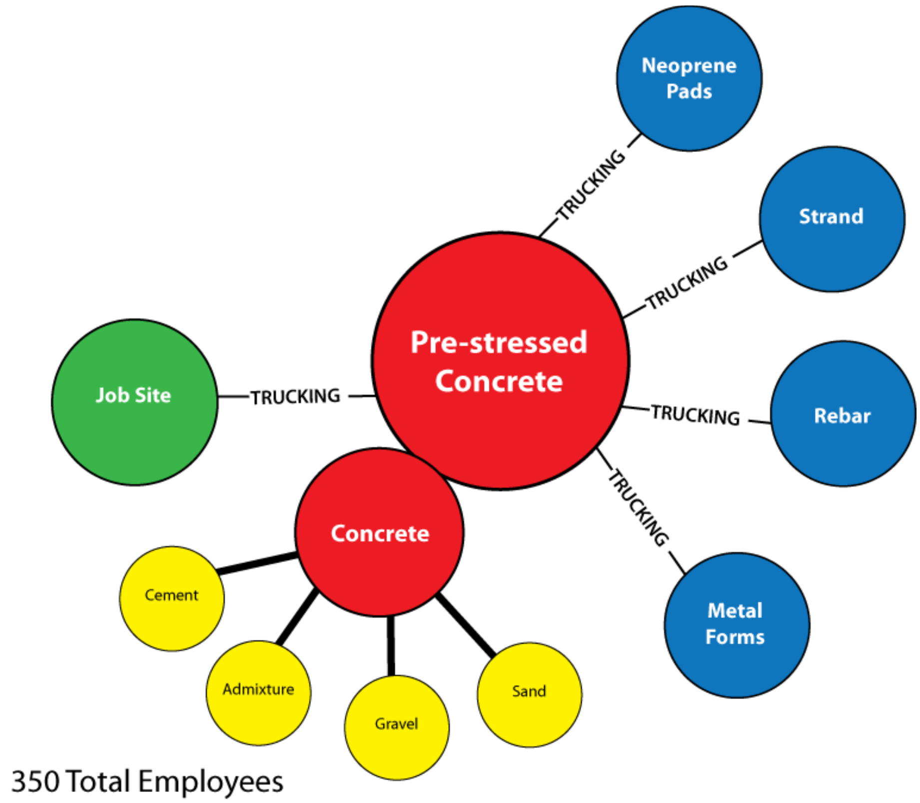


Figure 3.4: Supply chain for a typical pre-stressed concrete beam company

3.11.2 Process

Pre-stressed concrete beams require sand, gravel, cement, and strand (steel cables). The sand, gravel, and cement are obtained from suppliers in close proximity to the beam plants and are mixed to form concrete. The concrete is then poured into metal forms to create beams of varying dimensions and specifications. The steel cables (strands) are then used to place the beams in high compression, which gives them more strength than concrete alone.

Once the beams are produced, they are transported on trucks to the job site where they are installed. Neoprene pads are installed along with the pre-stressed beams to prevent warping and provide cushioning.

3.11.3 Employment Structure/Practices

This firm employs 350 employees across two locations throughout Texas. The primary plant employs 190 people at a given time, including 20 employees in upper management, 40 supervisors, and 130 hourly employees. Other support staff at both locations include 12 truck drivers, 3 mechanics, and 12 welders. The second location also includes a high percentage of hourly workers. Employees typically work in 9-hour shifts for 50 to 70 hours a week. When there is enough work at each location, workers rely on overtime to supplement their income.

3.11.4 Business Model- Costs

Major cost components for pre-stressed concrete beam companies are materials, labor, maintenance, and trucking/transportation. Trucking is the single-largest cost incurred by the company and represents between 15 and 20% of the total costs. Proximity to the job site is a factor in the final cost because the final product must be transported throughout the state. Fuel prices also affect the transportation costs. Additionally, escort vehicles often accompany shipments to their final destination at an additional cost.

This firm owns and operates six trucks and makes use of an outside trucking firm as well. The other costs (materials, labor, maintenance, etc.) each comprise a smaller percentage of the firm's overall operation expenses. Labor costs represent only 11% of the total costs to the firm, while maintenance expenses comprise 13%. Of the material costs, the steel strand is the most expensive (18 to 20% of total costs).

3.11.5 Job Estimates/Key Findings

During the economic downturn the company has been able to avoid layoffs, but in some cases has not replaced employees who voluntarily left. Skilled positions within the company require a fair degree of knowledge and experience, and the company has done its best to retain these workers. With some of its less-skilled hourly jobs, the company can ramp up fairly quickly for new work as needed. The company's owner feels that for some jobs in the company he can hire someone in the morning and have them contributing by the afternoon.

As this firm is a supplier to road construction contractors and not a direct bidder, it was difficult for the owner to gauge the direct impact of ARRA funding on his firm, although in general it was felt that it has had a positive effect. The owner mentioned several ARRA mobility projects that have brought or will be bringing additional orders for concrete beams and that will generate hours for his workers and revenue for his firm.

3.12 Excavation/Site Preparation Interview

3.12.1 Company Structure: Site Preparation Services Supplier

The company representative of the excavation/site preparation supply chain has operated for more than 30 years. This company is a prime contractor involved in a variety of types of civil construction, including excavation, utility and concrete installation, and paving. Figure 3.5 shows the supply chain.

Traditionally, this company's chief source of revenue has been commercial site projects, which comprised more than 60% of this company's workload in 2006. Since the recession and the passage of ARRA, this company has seen a marked decrease in its commercial contracts and a significant increase in public sector (particularly TxDOT) work.

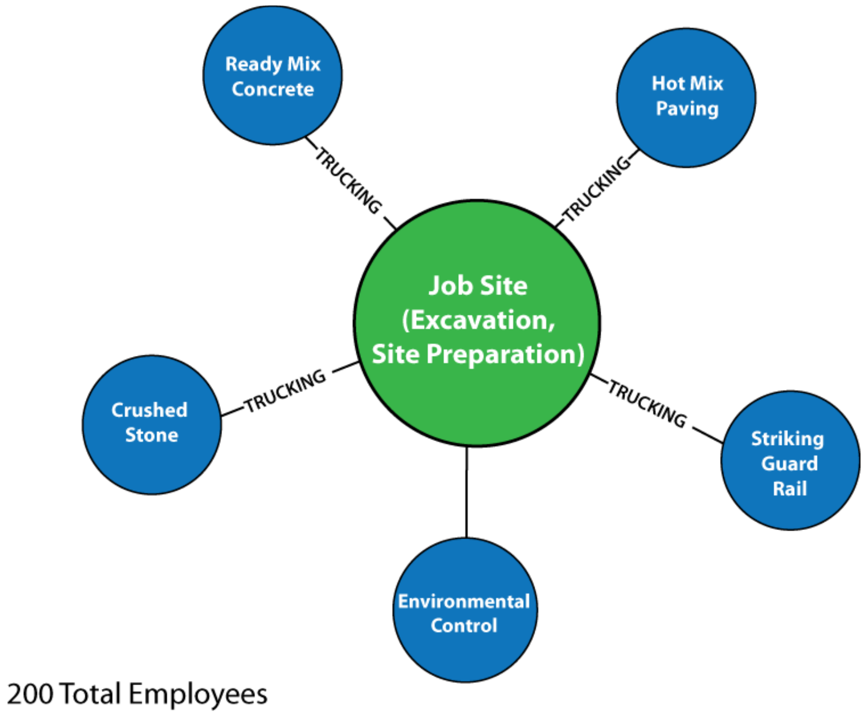


Figure 3.5: Supply chain for site preparation/excavation company

3.12.2 Process

Construction site preparation consists primarily of excavation of the work site and the installation of landscaping, drainage, and retention structures. Heavy earth-moving equipment is required to carve the landscape to the project's specifications and to make the site's surface level and compact. Then, steel or rebar is trucked in and laid on site to create the skeleton of any necessary retention barriers. Before concrete is poured onto the rebar frame, any utility lines or pipes must be installed underground. Finally, the frame is covered with concrete, effectively maintaining the shape of the construction site, supporting overall structure, managing soil erosion, and channeling water runoff.

3.12.3 Employment Structure/Practices

This company currently employs about 200 people. Of these 200, approximately 50 positions are salaried, administrative positions, or construction superintendents. The remaining employees are construction laborers, paid on an hourly basis.

Many administrative jobs, such as accounting and payroll management, are kept in-house, rather than contracting an outside firm. This company also retains its own surveyor position and keeps an equipment manager and mechanic on staff.

Because site preparation entails putting together the many different pieces of a structure, this company does not fabricate any of its own construction material. Rather, each component—rebar, steel, concrete, lime, aggregate, etc.—is transported by truck to the construction site.

3.12.4 Business Model

Because excavation focuses primarily on the use of heavy construction equipment, this company's business model can be characterized as capital-intensive. That is, this company currently owns more than four hundred units of heavy construction equipment, such as earth-movers, bulldozers, backhoes, and pavers. The initial cost and lifetime maintenance of this heavy equipment comprise a significant amount of the company's annual expenses.

This company also owns and maintains its 10,000 sq. ft. headquarters and a 10-acre lot with a maintenance facility.

Other expenses include labor, construction materials (forming materials, lime, hot mix, concrete, steel, rebar, pipe, etc.), banking, insurance, information technology, safety consultants, security, trade associations, etc. In 2009, this company wrote checks to more than 800 separate entities for services and materials provided.

Traditionally, this company has relied primarily on commercial construction for its contracts. In 2006, more than 60% of its workload was generated by private sector development. However, because of the recent economic recession and the subsequent passage of ARRA, this company presently relies on public contracts (TxDOT contracts in particular) for more than seventy percent of its work.

3.12.5 Key Findings

Poor market conditions have caused an increased reliance upon TxDOT contracts. This change in market conditions has also led to dramatic impacts in this company's use of capital. Since 2008, this company has been forced to cut its heavy equipment by more than 30%. It has also chosen to maintain its heavy equipment and its fleet vehicles for two to four years longer than it would have in the past. This company has seen a significant reduction of its workforce, which has been cut by 40% since 2008. Overall, ARRA has created no new jobs for this company through its stimulus, but ARRA has had a very positive influence on retaining this company's current workforce, preventing additional layoffs.

3.13 Transportation Services: Trucking Interview

3.13.1 Company Structure: Transportation Services−Trucking

This Texas-based trucking company specializes in transporting lime and asphalt from production facilities to job sites throughout Texas and connecting states, but 95% of its business is in Texas. Figure 3.6 shows its supply chain. Two primary hauling services are provided.

Lime Transportation: using trucks to haul lime to waste-water treatment plants, steel and paper mills, and road construction sites. In road construction, lime is mixed with local materials to provide a suitable stable material to form the road base. Construction jobs may only be 10% of their business, where it used to consist of 50% of their business. There has been a 50% decrease in demand in this portion of the business. Based on this the company sold 30 trucks last year.

Asphalt Transportation: using trucks to haul asphalt to road and building construction sites. The only two uses for this product are asphalt road construction and roofing shingles, so a drop in demand for one or the other affects demand substantially. Truck drivers must also receive training for the required hazardous materials certification to be licensed to transport asphalt on U.S. highways. Business in this area has decrease 15–20% this year, primarily due to a decrease in demand for roofing materials. Specialized heating tankers are needed to preserve the heat at 380 degrees during transport. They are based out of two or three specific terminals that utilize their services.

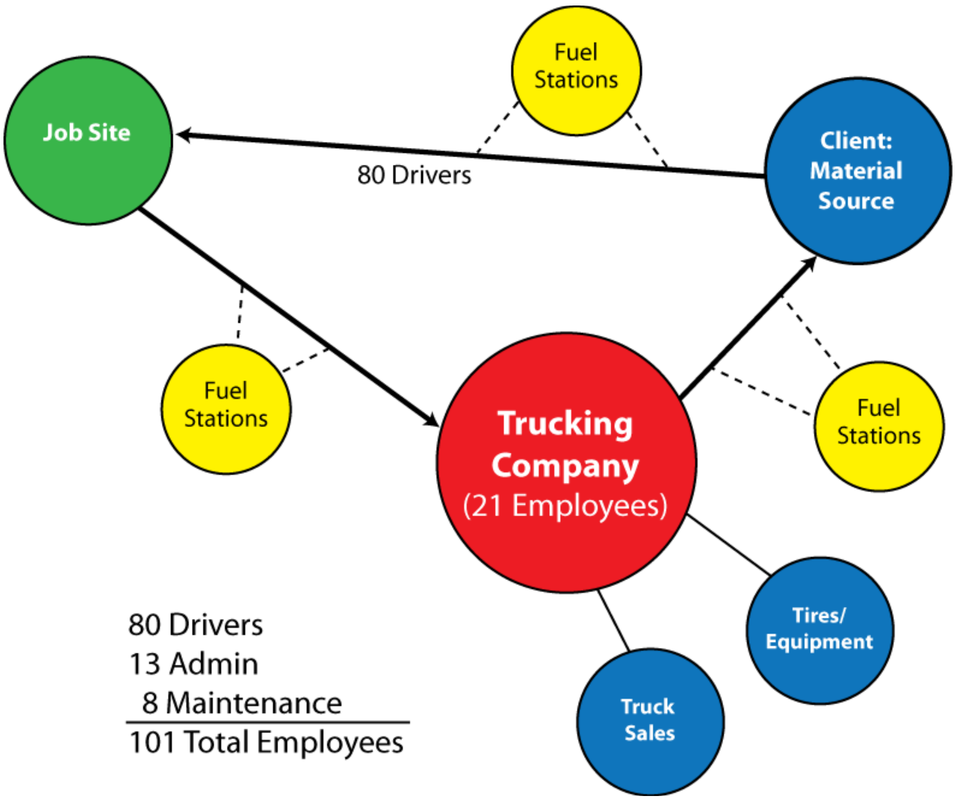


Figure 3.6: Supply chain for trucking company

3.13.2 Employment Structure/Practices

The selected transportation company currently has 101 employees consisting of 80 drivers, 6 mechanics, 2 tiremen, and 13 administrators (payroll, safety manager, dispatch). They currently own 93 trucks, which range in cost from $80,000 per trailer to approximately $195,000 for specialized tankers. In terms of maintenance costs, the company budgets $.15 per mile; they have their own mechanics and tire repair men. The company has a habitual relationship with a single truck manufacturing and separate tire dealer for material sourcing and higher-level repairs or replacement. Trucks are used on average for 6 to 8 years, a longer period than a typical trucking company, which averages 2 to 3 years.

There are three payment structures for truckers—either by the hour, by the mile, or by the gross. This company pays drivers by gross weight hauled, in which a typical load is 50,000 pounds of product, asphalt, or lime. On a good weather day, with nearby haul destinations, a lime truck can make three or four deliveries. However, drivers are limited by U.S. regulations and can only drive 12 hours per day and are subject to audits to enforce this. They more generally haul one load per day and normally return to the job site empty, affectionately referred to as the 'dead leg' or 'dead head.' In the industry this leg generates no revenue, and thus haulers will try to minimize empty returns by hauling something. With the specialty trailers, however, it is not possible.

The company provides drivers comparable pay and the best working conditions available. This company has not paid any overtime to non-driving employees over the past year. The company utilizes speed governors on all of its trucks. By introduction of these units, they estimate they have realized 10–12% better fuel economy from reduced vehicle speeds, which are less fuel efficient. Their fleet averages a little less than 6.5 miles to the gallon, which shows their interdependence on fuel costs for service. At times they have charged fuel surcharges to pass some of the fuel spike fees on to customers, but the 25 surcharge is levied at the beginning of the month/contract and may not reflect the actual price paid at the pump, which also impacts cost margin.

3.13.3 Business Model

This company has long-standing relationships with producer customers (two lime and six asphalt) that provide the bulk of its business. It competes directly with five other companies in this market for emerging business. The company is currently hiring up to 13 additional drivers (16% added capacity) in anticipation of increased demand this spring and summer, when business historically picks up. Approximately 35% of the trucking's business is TxDOT related, but it has not seen any significant change from increased ARRA funding.

3.13.4 Job Impact Estimates

The company is not overly typical of the trucking industry, in that it has dedicated clients, making it more fortunate than a trucking company that continually needs to compete for jobs. However, this company does have to compete with those companies, including some from out of state that have come to 'eat their lunch,' in seeking to add the relatively better current economic environment of Texas to their base area. When the company is not making revenue from hauling jobs, they are not able to pay drivers. Thus, the recession has impacted this company and required them to reduce their number of drivers. As noted above, however, this company is optimistic about the pending work and is looking to hire up.

Based on this interview, it is accurate to say that this company, and industry, is very sensitive to fluctuations in work availability, where 90% of the employees are directly dependent on constant work to receive pay. Commercial development drives the demand for this company's service. Their costs are flat rates—based on wages and fuel cost, with very little room for flexibility to save on those costs.

Figure 3.7 diagrams the nested supply chain.

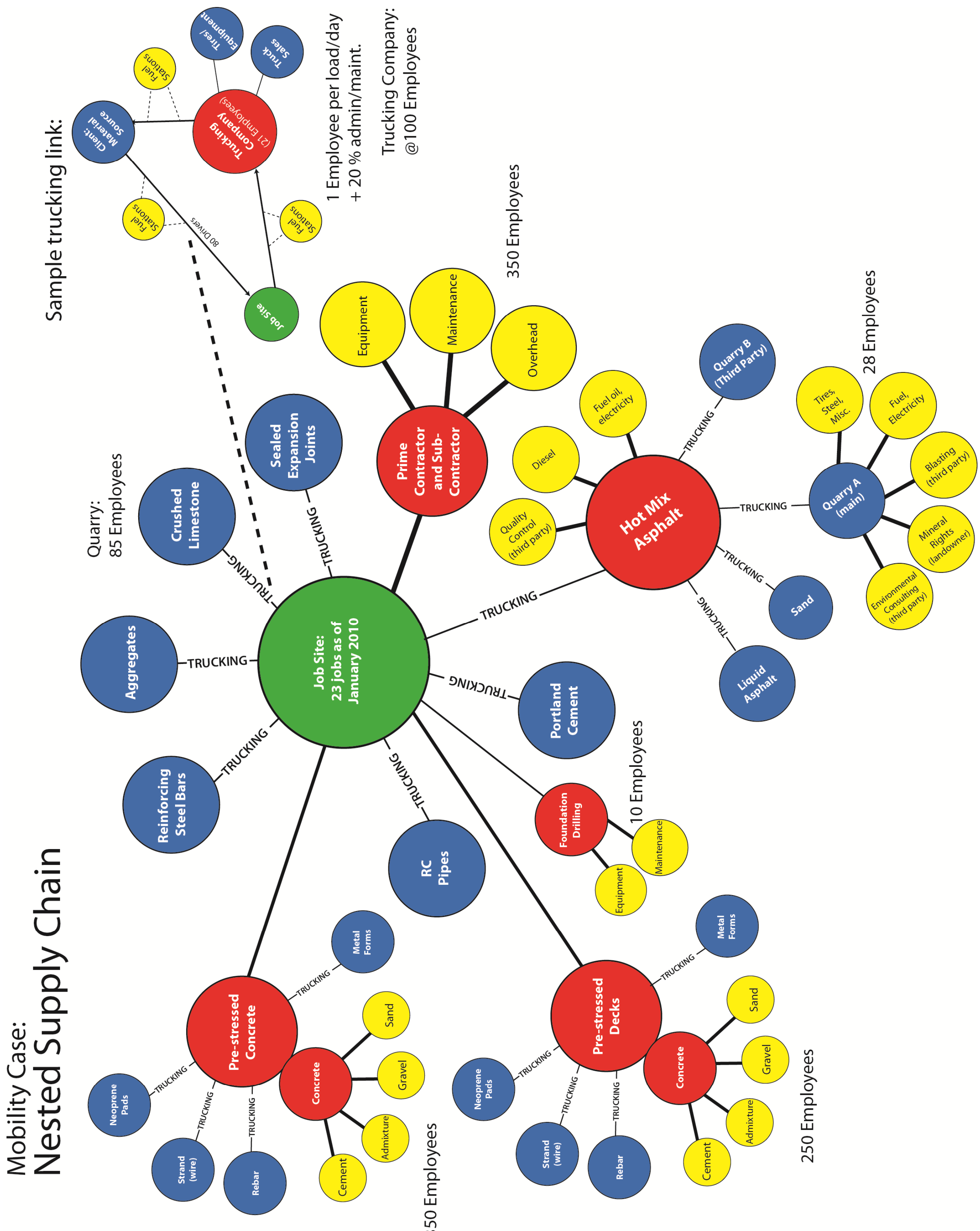


Figure 3.7: Mobility Case: Nested Supply Chain

3.14 Key Findings

The interviews with these five companies representative of the construction industry resulted in the emergence of common themes, or key findings, among the entities. They are as follows.

3.14.1 Shift in Business Model

Almost all of the companies interviewed, with the exception of the pre-stressed concrete beam firm, had a business model that was partly supported by the private-sector commercial business. Consequently, due to the recent economic downturn and the lack of commercial work available, these companies had to adapt their business model to the changing economy. For many of these companies, this meant increasing their public portfolio. The hot mix firm increased its business with public entities by 15%; the trucking firm more than doubled its business with TxDOT. The excavation firm's business with TxDOT is up to 70%, from 40% just three years ago.

Due to the influx of new firms in the public market, coupled with the overall economic downturn, all of the companies interviewed were forced to vastly reduce their bid estimates on TxDOT projects. As a result, their business models have shifted to accommodate not only less demand overall, but also a reduction in profit percentages per contract. These shifts in the business model helped to sustain these companies during this economic downfall and period of recovery.

3.14.2 Overall Impacts of ARRA funding

At the time of the interviews, which took place in March 2010, most of the participants were aware of having worked on one job or more in which ARRA stimulus funds were applied. One major exception is the asphalt emulsion contractor, who was unaware of having manufactured any products that were used in ARRA-funded projects.

The majority of the companies interviewed believe that the stimulus money has positively affected their business; the trucking company saw no visible impact on its business due to ARRA funding. The asphalt emulsion firm is unique in noting that the ARRA funding negatively impacted its business, due to the re-allocation of funds from preventative maintenance projects (in which chip seals, one type of asphalt emulsion, are commonly used) to rehab projects where ARRA money would not cover the entire expense. As a result, not only did the firm not gain any business from ARRA funded projects, it lost some business from TxDOT due to this re-allocation of funds.

3.14.3 Reporting Issues

One area of interest in our study is the accuracy of reporting for ARRA jobs data. We hoped to capture direct, indirect, and induced impacts of the ARRA funds being used on TxDOT projects. While we were satisfied by the data produced by the ARRA reporting requirements for direct impacts, we found other areas were more difficult to quantify based on the current reporting and data.

Current federal requirements have stringent monthly requirements to quantify numbers of workers present at ARRA jobs. We assessed that the job numbers that come from these reports are relatively accurate for capturing direct employment data. The method specified for collecting this data does create the possibility for errors in a few areas. First, the report is only a one-day snapshot per month of the job site and might not capture other workers employed by the project during the month based on the work schedule. Additionally the job number is based on work hours converted into full time equivalents (FTE). There could be more workers if part-time or overtime labor is being used. Finally, the ARRA job reporting fails to account for other members of firms such as mechanics, supervisors, engineers, etc., that are employed by the ARRA project because they are not directly on the site. Despite these potential shortcomings we still believe that 27 data provided by these reports gives the public a reliable method of determining how many people were actually working on the job site.

The reporting requirements for ARRA jobs fail to capture indirect impacts of these projects. There are a number of suppliers, subcontractors, and other area businesses that are indirectly employed because of ARRA projects. There is no reporting requirement to capture this data, and it would be quite difficult for many of these businesses to accurately quantify how many workers this project allowed them to employ. While it would be possible to add additional reporting requirements to attempt to follow the dollars provided to these projects, it is not clear if the added data would be reliable enough to justify the additional cost and effort. We found the best way to build a picture of the indirect impacts was analyzing suppliers with the help of the AGC. As mentioned previously this at least provided depth to our understanding of the jobs supported by the project that are not necessarily on-site or part of the prime-contractor's firm.

Finally, there is no way to accurately quantify the induced impacts of these TxDOT projects. While the induced impacts of these projects are intuitive, we found no way to capture the data. There is no method to track the millions of dollars being pumped into the Texas economy and its impact on sales and consumption across the spectrum of the entire market. Beyond the induced impacts of the dollars, we found no reliable method to quantify the impact of these projects on the economy writ large. We studied several models but found that each one was built on potentially faulty assumptions.

3.14.4 Job Impact Estimates

Direct

All interviewees confirmed that the job counts reported were reasonably accurate. In terms of job impact estimates, the ARRA funding did not create jobs for any of the participants. However, as seen throughout this interview process, the funds helped companies retain employees and increase payroll hours. In the cases of both the hot mix and excavation interviewees, the influx of ARRA funding helped to postpone additional layoffs from occurring; the stimulus funding was particularly crucial for the excavation participant, whose firm has seen its workforce reduced by almost 40% since 2008. Given that unskilled laborers are first impacted by declining business, it is likely that these funds helped to avoid additional losses in this category.

In looking towards the future, it is unlikely that the injection of further stimulus money into many of these companies will impact direct employment in terms of additional hires unless a long-term, sustained increase in demand was developed. This is especially true for the hot mix asphalt firm, which relies heavily on automation in all of its production stages, and the pre-stressed concrete beam firm, whose owner does not replace employees who have voluntarily left in an economic downturn. This type of long-term growth will only come from the private sector; therefore the commercial construction industry will need to fully rebound before we see an increase in the number of direct hires in this industry.

Indirect

While the injection of stimulus funds may not have an impact on direct employment, those interviewed believe that it will greatly affect indirect employment. As outlined previously, many of the interviewed firms' subcontractors and suppliers rely heavily on the flow of money from these primary businesses. In particular, the owner of the hot mix asphalt plant believes that its trucking subcontractor and sand supplier would benefit most in terms of employment related to additional business generated by stimulus funds. In terms of indirect impacts in the pre-stressed concrete beam supply chain, the owner believed that the metal forms company, which requires highly skilled labor, would be most responsive; this is partly due to changes in TxDOT standards that would require new metal forms to be built. While these companies have predictions of where the indirect impacts may take place, it is difficult to quantify without a formal tracking system or the ability to disaggregate the sales generated by ARRA projects as opposed to other projects.

Induced

While many of the interviewees did not shed much light on the induced impacts in relation to stimulus funding, the hot mix asphalt owner made clear the ties between their business operations and induced impacts in the surrounding area. All of the employees live in close proximity to the plant and quarry locations, and their spending contributes to the local economy. Furthermore, the company relies on the local suppliers for many of its needs, creating another route for funds to enter the local economy via the asphalt plant. Finally, the owner notes that the property taxes paid on the vast quarry site funds a number of teaching positions in the area's school district. Ultimately, funds pass through the primary hot mix business to suppliers, subcontractors, and the local economy. While there are certainly induced impacts related to spending by all of the companies interviewed, again they are difficult to quantify.

Long-Term Impacts

While the ARRA stimulus funding may not have succeeded in generating new jobs in the construction industry, it will have an impact in job creation long term. The construction of new highways and roads helps to facilitate the flow of goods and people throughout the state. This increased ease of flow leads to existing companies reducing their shipping and trucking costs, allowing them to invest in expansion and, ultimately, the creation of additional jobs. Furthermore, new companies will be built around, and existing companies will relocate to, areas in the state in which roads are fully developed and maintained; this in turn will bring new job opportunities to the local area.

3.15 Recommendations

The supply chain methodology developed in this study has helped highlight the impact of ARRA funds beyond the direct jobs reported as funds pass through the primary contractor. However, the framework developed in this study may have value beyond the overarching conclusions developed to this point. First, the supply chain method can be further developed to understand the relative impacts for indirect jobs by sector or by region. This can be accomplished by creating supply chains via interviews with several additional contractors within the specific road construction sectors and/or within specific regions in Texas. The additional interviews may establish which specific sectors and regions are most responsive in terms of job creation or retention when funds are injected—this does not necessarily need be a quantitative measure, but rather can be based on the general sector or regional trends observed in the interviews. However, if further quantitative data is desired in terms of indirect jobs throughout the supply chain, the first step would be additional reporting requirements of funds passing through the supply chain.

Suppliers and subcontractors would need to know that the funds they receive are specifically related to ARRA or some other specific program; further, they could provide job data in return as has been the case for the prime contractors thus far. The downside is the additional burden of collecting this data and feasibility of ensuring its accuracy as funds are distributed—this must be weighed against the value of the additional data. Additionally, the supply chain interviews in this study were limited to a focus on indirect jobs. Induced impacts as employees spend funds from ARRA were not considered in detail due to the difficulty and time required to collect this data. However, the supply chains and contacts developed to this point could also be used to develop general information and conclusions on induced impacts. Some of the contractors seemed open to the idea of providing general information about their employees, which could be used to map induced impacts as well. A group could focus on this specific aspect and potentially develop a method to understand induced impacts.

Finally, our group has pursued this study without the use of commercially developed economic impact models that attempt to quantify job impacts from economic development or activity. Our primary reason for avoiding the use of the modeling method was a lack of transparency into the assumptions and methodology of modeling software. The ARRA funding occurred at a unique time of low economic activity, particularly in comparison with the rapid economic growth in the years prior to the downturn. Thus, the assumptions made in any quantitative method must reflect the impact of the overall economic conditions on job impacts; we found no clear way to verify these assumptions. The same problems occur as individual sectors and regions are analyzed: each is susceptible to specific assumptions regarding job impacts—this was seen in the variation in our different supply chains. We will not recommend for or against the use of models, as they may have value in future studies. However, we do recommend than any quantitative method should clearly outline its assumptions and these assumptions should be verified by a field method, such as our supply chain interviews. This transparency is of particular importance in the public sector—a simple model output without detailed methodology will be difficult to support against criticism.

3.16 Conclusion

Our goal in this course was to assess the impact of ARRA funds provided to TxDOT. Ideally we hoped to provide employment numbers and perhaps develop or recommend a model that TxDOT could use to assess job impacts in the future. Unfortunately, this proved too difficult to accurately provide due to reporting challenges and inaccuracy of available models. We are confident, however, that these projects did in fact create a number of additional hours for Texas businesses and this saved jobs throughout the state. As one of our contractors said, “ARRA funds didn’t create many jobs, but it saved an industry.”

Chapter 4. Pavement Condition Predictions based on TxDOT Funding Projections

4.1 Introduction

Task 8: Pavement Condition Predictions based on TxDOT Funding Projections

The objective of this task was to calculate future pavement Condition Scores using the same methodology and assumptions as were used in the 2030 Pavement Needs study, but based on the current projected funding allocations.

4.2 Task Report

Pavement Condition Analysis Based on TxDOT Funding Projections
November 16, 2009
Authors: Zhanmin Zhang, Michael R. Murphy, Khali R. Persad, and Robert Harrison

4.2.1 Introduction

In the "2030 Pavement Needs" study completed in early 2009, CTR produced funding needs estimates to achieve and maintain specified pavement Condition Score levels from the 2008 to 2030. More recently, TxDOT developed a long term funding scenario using the TRENDS program, with input from MPOs, district engineers, and the Texas Transportation Commission.

However, it was noted at the August 2009 Commission meeting, that the TRENDS projected pavement funding allocations from FY 2010 to FY 2030 are below CTR's needs estimate to achieve and maintain 80% 'Good' or better pavement Conditions. As a result, TxDOT Administration has requested CTR to analyze future pavement Condition Scores using the same methodology and assumptions as was used in the 2030 Pavement Needs study, but based on the current projected funding allocations.

The funding allocations for FY 2010–FY 2013 are based on the 4-year Pavement Management Plans. The FY 2014–2035 funding projections are based on the TRENDS analysis. Using these funding allocation projections TxDOT desires Pavement Condition Score predictions at 5-year increments starting with year 2015.

4.2.2 Analysis Assumptions

Key assumptions used in the analysis and prediction of the pavement conditions under the budget scenario provided by TxDOT are discussed as follows.

Pavement Network

The pavement network with which the analysis was conducted consists of the existing pavements under TxDOT's jurisdiction and is stored in the existing PMIS database. The most current version of the PMIS database was used in the analysis, based on the 2009 PMIS data collection.

Base Year Network Condition

The base year of the analysis was 2009. The condition of the entire state's pavement network was initially determined based on the individual scores of the pavement sections in the PMIS database. The Condition Score of these sections was used as the performance measurement index to calculate the "Good" or Better Pavement Scores.

4.2.3 Deterioration Models

Before planning for the Maintenance and Rehabilitation (M&R) actions for the road network, the deterioration process of the pavements was studied in order to understand when their condition would reach a critical level that would trigger intervention. In this study, a statistical analysis was carried out to analyze the deterioration rate distribution for the different pavement structure types and highway functional classifications. As a result, nine broad groups of deterioration models were defined as presented in Table 4.1.

Table 4.1: Summary of Nine Groups of Deterioration Models

Highway Functional Class		**Pavement Type**		
		Flexible	**Rigid**	
			CRCP	**JCP**
Interstate Highways	IH	Group 1	Group 4	Group 7
US Highways	US			
State Highways	SH	Group 2	Group 5	Group 8
Farm-to-Market	FM	Group 3	Group 6	Group 9

These nine groups were found to have distinctive deterioration rates; and therefore a different set of models were developed for each group.

It is also known that the daily temperature range and the precipitation play an important role in the pavement deterioration process. As a result, instead of developing pavement condition models for every district in Texas, these models were developed instead for the four climatic regions of Texas, as shown in Figure 4.1. For each climatic region, separate pavement condition models pertaining to the Distress Score and the Ride score were developed.

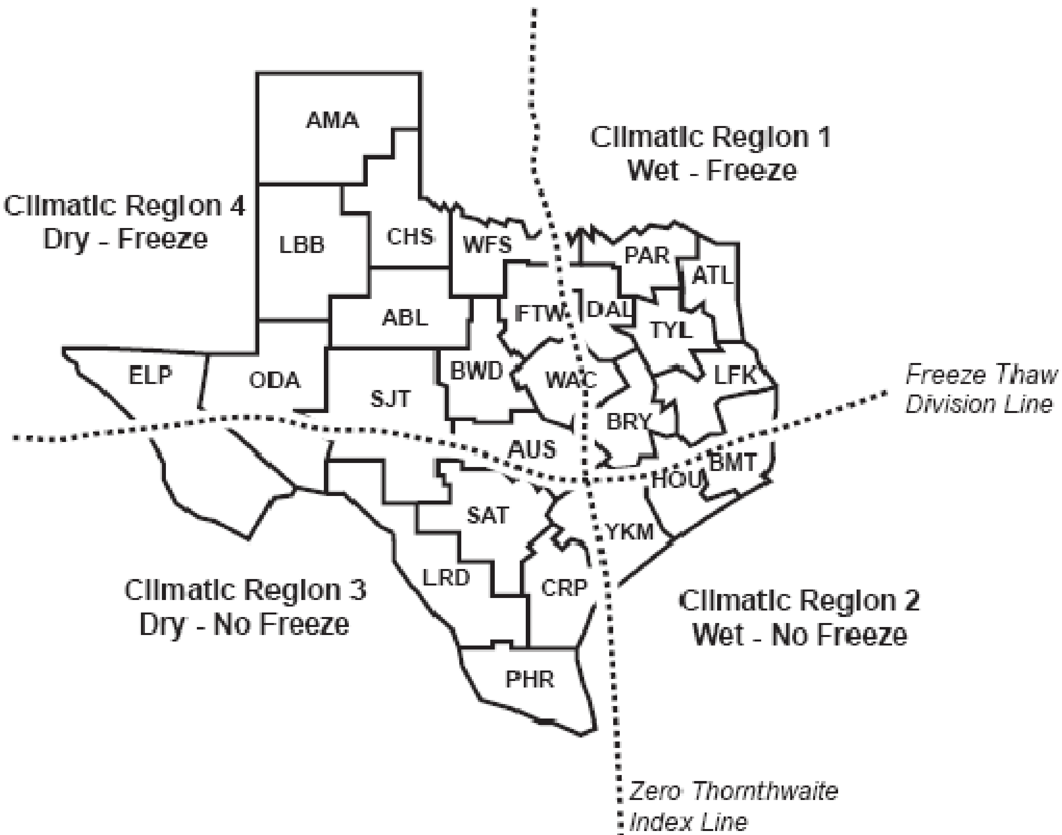


Figure 4.1: Climatic Regions in the State of Texas

4.2.4 Next Year Network Condition

The condition of the network for each subsequent year was based on the condition of the previous year with the addition of the effect of the natural deterioration and the M&R work planned for the previous year. Once these new values in terms of the Ride Score and their Distress Score were determined then they were combined together to calculate the new Condition Score of each section. The new Condition Scores of each sections were then averaged together weighted by their respective lane-miles to get the new state-wide Condition Score.

4.2.5 Maintenance and Rehabilitation Costs

Finally, the implementation of each treatment action corresponded to a specific cost for the agency, based on the unit cost of the action by lane-mile treated and the lane-miles of the treated section(s). The unit costs of each action were set to the values shown in Table 4.2, and were different for flexible and for rigid pavements. These values are consistent with the 2030 analysis. The treatment costs used in the 2030 Pavement Needs Estimate and the analysis undertaken in this study are based on project delivery costs, which include estimated costs for mobilization, traffic control, materials, labor, and ancillary items necessary to actually complete the pavement project. These costs generally differ from PMIS treatment costs, which primarily include the cost for pavement materials (i.e., hot mix, portland cement concrete, etc.). In addition, the treatment costs used in this analysis are based on constant FY 2008 dollars whereas the PMIS treatment costs are based on constant FY 1993 dollars.

Table 4.2: Maintenance and Rehabilitation Action Unit Costs

M&R Action	Unit Cost (per mile per lane) for Flexible Pavements	Unit Cost (per mile per lane) for Rigid Pavements
Needs Nothing	$0	$0
Preventive Maintenance	$29,000	$36,000
Light Rehabilitation	$173,000	$60,000
Medium Rehabilitation	$237,000	$256,000
Heavy Rehabilitation	$442,000	$651,000

4.2.6 Maintenance and Rehabilitation Improvements

Each M&R action was assumed to have a specific effect on the section it was applied to, in terms of the section's Ride Score and Distress Score. The correspondence between the various M&R actions and their respective effect on a pavement are shown in Table 4.3.

Table 4.3: Maintenance and Rehabilitation Action Improvements

M&R Action	Ride Score Improvement	Distress Score Improvement
Needs Nothing	0	0
Preventive Maintenance	0.5	95
Light Rehabilitation	1.5	100
Medium Rehabilitation	Reset to 4.8	Reset to 100
Heavy Rehabilitation	Reset to 4.8	Reset to 100

4.3 Data Used in the Analysis

Two categories of data were used in the analysis: 1) PMIS pavement condition data, and 2) funding allocations for pavement preventive maintenance and rehabilitation. More specifically, Category 1 Preventive Maintenance and Category 1 Rehab funding were used in the analysis. Funds from additional sources such as the Federal Stimulus Package, Proposition 12, and Proposition 14 were also used where applicable.

4.3.1 PMIS Data

FY 2002 to FY 2009 PMIS data provided by TxDOT was used in the conduct of this analysis.

4.3.2 Funding Allocations and Projections for FY 2009 to FY 2035

Pavement funding allocation for FY 2009 is based on the TxDOT 4-Year Pavement Management Plans. The funding projections for FY 2010 to FY 2020 are based on the UTP funding levels provided by the TxDOT Administration. Funding projections for FY 2021 to FY 2035 are based on the TRENDS analysis results provided by TxDOT.

4.4 Analysis Results

Using the PMIS pavement condition data, the funding allocations and projections provided by TxDOT, and the assumptions discussed in the earlier sections of this technical memorandum, the pavement condition analysis was conducted with the algorithms and procedures developed by CTR. The projected pavement performance in terms of the "Good" or better pavement scores for FY 2010 through FY 2035 are presented in Table 4.4, along with funding allocations and projections.

Table 4.4: Summary of Pavement Funding Allocations and Projected Pavement Performance for FY 2010 to FY 2035

Year	Cat 1 Total	Cat 1 Total (Net Present Value in 2008 Dollars)	"Good" or Better Score (%)
2009(Base Year)	$1,198,984,327	$1,164,062,453	85.94*
2010	$391,704,544	$369,219,101	84.94
2011	$852,064,920	$779,760,105	81.58
2012	$1,289,503,110	$1,145,706,811	78.60
2013	$879,207,181	$758,411,838	75.75
2014	$927,844,163	$777,054,879	70.94
2015	$940,402,463	$764,633,260	65.43
2016	$1,063,647,825	$839,653,415	58.90
2017	$1,086,722,706	$832,882,466	51.87
2018	$1,071,532,346	$797,320,698	45.13
2019	$1,082,852,781	$782,275,889	38.93
2020	$1,082,852,781	$759,491,154	33.72
2021	$1,368,355,161	$931,783,281	29.39
2022	$1,321,384,391	$873,590,749	26.70
2023	$1,249,795,875	$802,196,414	24.27
2024	$1,173,006,070	$730,978,602	22.36
2025	$1,055,721,023	$638,728,581	20.65
2026	$1,027,531,254	$603,566,318	19.12
2027	$971,083,323	$553,795,250	17.73
2028	$814,036,117	$450,712,061	16.36
2029	$632,832,652	$340,178,734	14.98
2030	$439,742,216	$229,498,165	13.56
2031	$547,767,401	$277,549,222	12.02
2032	$422,312,886	$207,749,956	10.72
2033	$306,765,814	$146,513,061	9.41
2034	$200,624,889	$93,028,703	8.16
2035	$103,333,911	$46,519,796	6.94

*Measured score, as 2009 is the base year of the analysis.

The “Good” or better pavement condition scores for FY 2015, FY 2020, FY 2025, FY 2030, and FY 2035 are highlighted in Table 4.4. As it can be seen from Table 4.4, the “Good” or better pavement condition scores are 65.43, 33.72, 20.65, 13.56, and 6.94 for FY 2015, FY 2020, FY 2025, FY 2030, and FY 2035, respectively.

The predicted pavement performance trend for FY 2010 to FY 2035 is also presented in Figure 4.2, along with the measured pavement performance trend for FY 2002 to FY 2009.

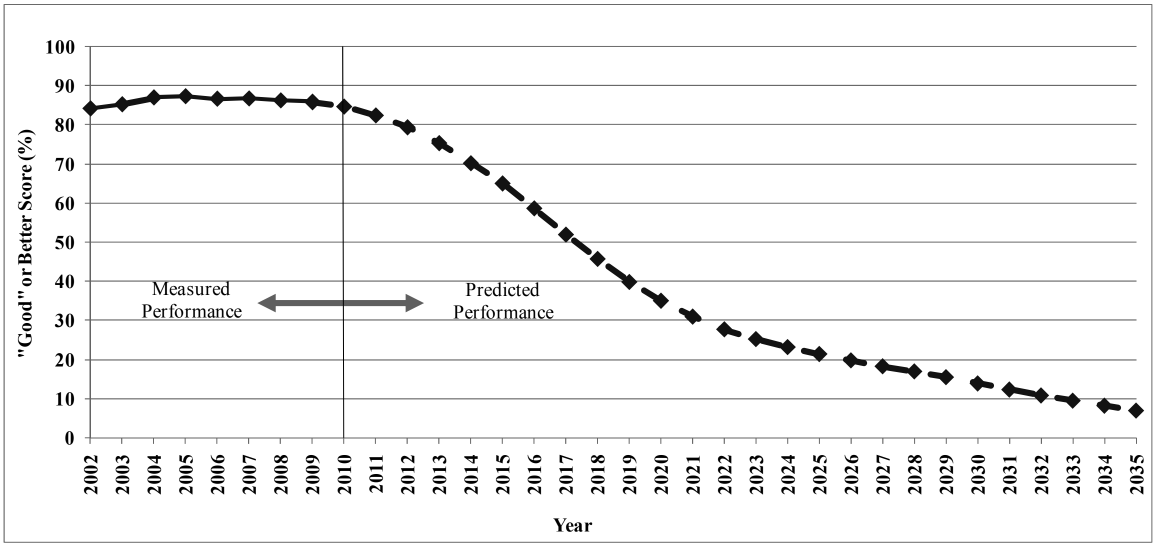


Figure 4.2: Predicted Pavement Performance Trend for FY 2010 to FY 2035 Based on TxDOT Funding Projection

4.5 Conclusions

This analysis was conducted with funding allocations and projections provided by TxDOT, where the funding allocation for FY 2009 is from the 4-year Pavement Management Plans and the funding projections for FY 2010 to FY 2035 are based on the UTP funding levels and the TRENDS analysis. Based on the analysis results, it is obvious that these funding allocations and projections are significantly below the funding needs required to achieve and maintain the 80% ‘Good’ or better pavement Conditions that were estimated under the 2030 study. More specifically, with the current funding allocations and projections, the ‘Good’ or better pavement score will drop below 80% by year 2012; and by year 2018, the score will drop below 50%. The “Good” or better pavement condition scores are 65.43, 33.72, 20.65, 13.56, and 6.94% for FY 2015, FY 2020, FY 2025, FY 2030, and FY 2035, respectively.

Chapter 5. Identification of Economically Depressed Areas in Texas

5.1 Introduction

Task 9: Identification of Economically Distressed Areas in Texas

The objective of this task was to identify areas (a region, metropolitan area, municipality, smaller area within a larger community, or other geographic area) that would qualify as an economically distressed area (EDA) as defined by the FHWA under the ARRA, and to determine which TxDOT projects were planned for those areas.

5.2 Task Report

Identification of Economically Distressed Areas in Texas
December 18, 2009
Authors: Khali Persad, Guohui Zhang, Mike Dobbins, and Tanveer Hayat

5.3 Introduction

This technical memorandum documents an analysis performed by CTR to identify the proposed transportation projects located in economically distressed areas (EDA) of Texas. Specifically, the projects examined are those proposed by the Texas Department of Transportation (TxDOT) as "Plan B Projects" using American Recovery and Reinvestment Act (ARRA) of 2009 funds.

5.3.1 Scope of Work

1. Use the per capita income and unemployment rate data that was the basis for the March 13, 2009 map of EDA counties and determine if any other areas (a region, metropolitan area, municipality, smaller area within a larger community, or other geographic area) would qualify as an EDA.

2. Use the provisions for Special Needs as described in the FHWA Supplemental Guidance on the Determination of Economically Distressed Areas (http://www.fhwa.dot.gov/economicrecovery/guidancedistressed.htm) and determine the areas (a region, metropolitan area, county, municipality, smaller area within a larger community, or other geographic area) that would qualify as an EDA.

3. Take the additional EDA's identified in Tasks 1 and 2 and identify any projects that would lie in those areas from the list of projects that have already been selected/identified or are plan "b" type projects. The list of projects will be supplied by the department.

5.4 Research Approach

The following are the main steps followed in this research:

1. Obtain data from TxDOT on "Plan B" project locations and characteristics.

2. Determine ARRA criteria for EDA.
3. Obtain economic data for Texas at the deepest level available (from multiple sources).
4. Develop GIS display for Texas of economic data and project locations.
5. Prepare tables, maps, and summary information showing "Plan B" projects that qualify as EDAs.

5.4.1 Primary ARRA Criteria for EDA

- An EDA may be a county, region, municipality, smaller area within a larger community, or other geographic area.
- Unemployment rate (for the most recent 24-month period for which data are available) is equal to or greater than 1% above national average.
- Per capita income is less than or equal to 80% of national average.

Source: http://www.fhwa.dot.gov/economicrecovery/guidancedistressed.htm

5.4.2 ARRA Criteria for 'Special Need' EDAs

- Actual closure or restructuring of one or more businesses within the past 12 months, resulting in sudden job losses.
- Department of Defense base closures or realignments, defense contractor reductions-in-force, or Department of Energy defense-related funding reductions.
- Major disasters or emergencies, including terrorist attacks, if the area has received a Presidential disaster declaration within 18 months prior.

Source: http://www.fhwa.dot.gov/economicrecovery/guidancedistressed.htm

5.4.3 Sources of Economic Data

- National
  - Census Bureau
  - Bureau of Labor Statistics (BLS)
  - Bureau of Economic Analysis (BEA)
  - Federal Reserve
  - University of Chicago
- State of Texas
  - Comptroller's Office
  - Texas Workforce Commission
  - County offices and Chambers of Commerce

5.4.4 Issues with Economic Data

- Unemployment and per-capita income figures from different sources vary significantly
- Data changes monthly, so need to select specific date for each analysis
  - October 2008 is FHWA benchmark, but not all Texas data for October 2008 available
- Census Bureau is primary data source for FHWA, but:
  - October 2008 per-capita income available for only 117 counties of 254. Newer data is also partial
- Bureau of Economic Analysis (BEA) data:
  - October 2007 per-capita income available for 200+ counties

As requested by TxDOT: For each ARRA criterion, use data from a *nationally recognized source* for a specific period within last 2 years, preferably in 2008–2009. This standard relegates the use of data from local sources, *which are the only sources of data at sub-county level.*

5.5 Results

The following charts and tables summarize the results of the analysis (Figures 5.1 through 5.4 and Tables 5.1 through 5.5).

5.5.1 TxDOT Proposed "Plan B" Projects

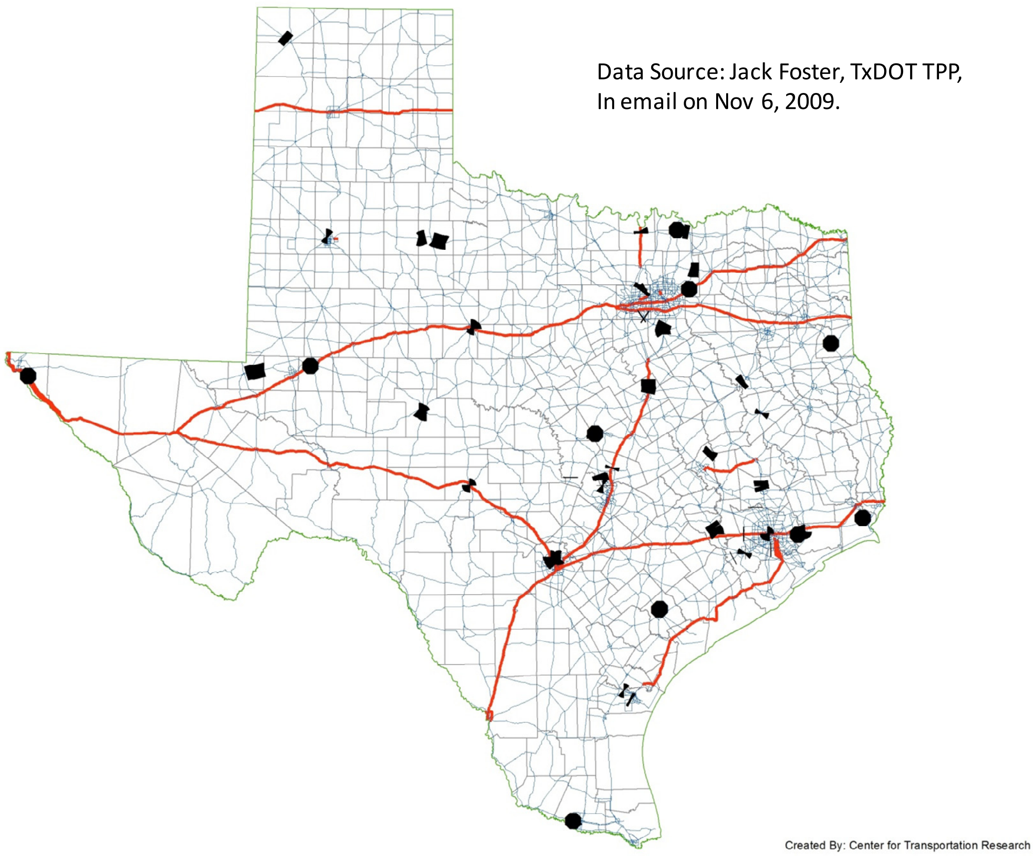


Figure 5.1: TxDOT Proposed "Plan B" Projects

Table 5.1: Summary of TxDOT Proposed "Plan B" Projects

Source: List provided by Jack Foster, TxDOT TPP on November 6, 2009

Region	Number of projects	Dollar value
North	17	$285,352,017
South	16	$177,413,309
East	18	$524,173,981
West	11	$358,264,039
Total	**62**	**$1,345,203,346**

5.5.2 Texas Unemployment Rates 2008

Criterion for EDA qualification: Employment rate 1% or greater than national average. The latest year for which unemployment data is available from the Bureau of Labor Statistics is 2008, in which the national average unemployment rate was 5.8%. Adjusted and unadjusted data are also available for several months in 2009, but is a sampling of counties, not for every county. The following chart from the Bureau of Labor Statistics shows Texas counties that had an average 2008 unemployment rate of 6.8% or greater.

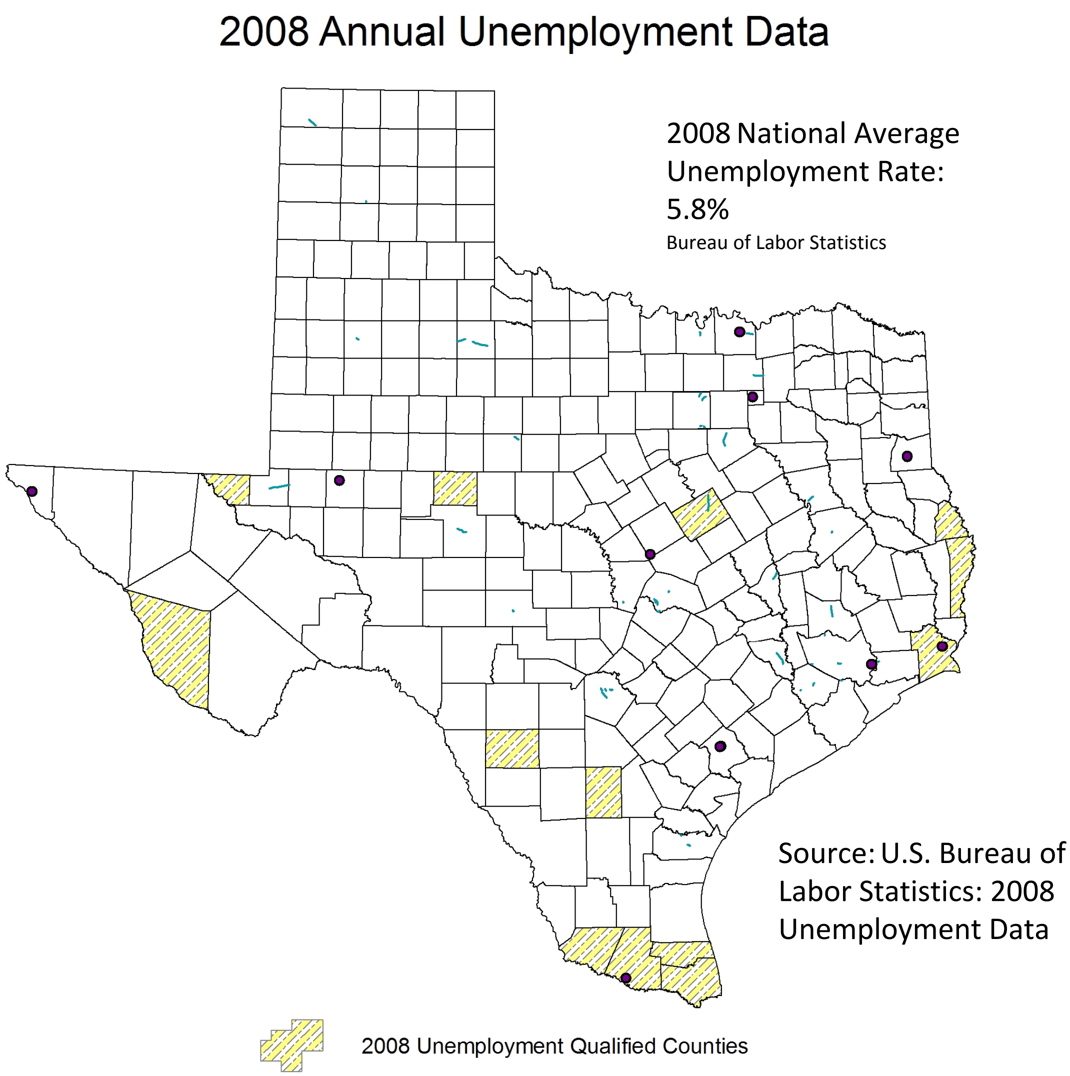


Figure 5.2: Texas counties qualifying as EDA: Average unemployment rate in 2008 equal to or greater than 6.8%

Table 5.2: List of counties (13) qualifying as EDA by 2008 unemployment rates

COUNTY	Unemp_2008	Sept_2009_U	Oct_2009_U
Cameron	6.8	10.8	10.5
Coke	7.7	8.6	8.5
Hidalgo	7.3	11.6	11.2
Jefferson	6.8	10.8	10.9
Loving	8.9	11.5	9.6
McLennan	7.0	11.2	10.9
McMullen	11.0	13.6	14.2
Newton	7.3	12.4	11.8
Presidio	10.8	17.8	18.0
Sabine	9.2	15.9	16.3
Starr	11.9	17.8	18.3
Willacy	9.0	13.9	13.3
Zavala	10.8	16.3	15.7

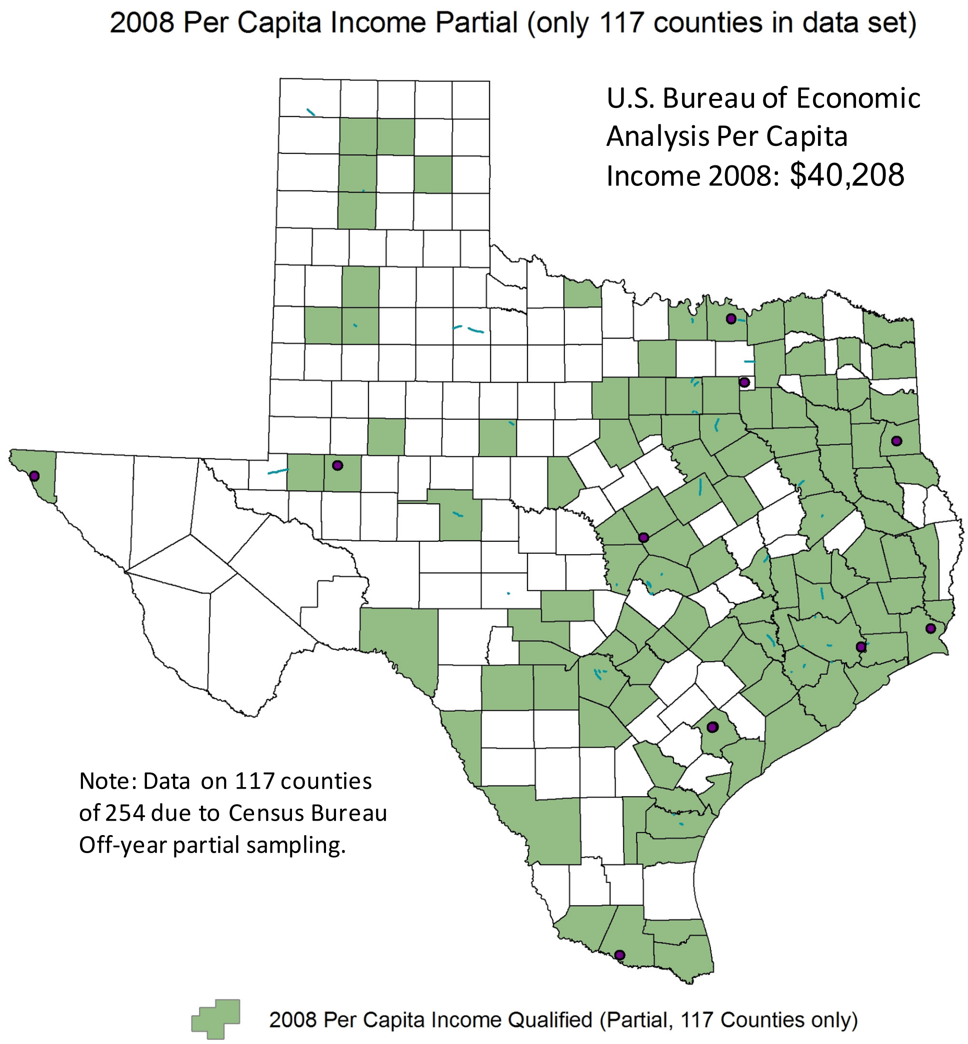
Table 5.3: List of "Plan B" projects qualifying by 2008 unemployment rates

CSJ	District	County	Highway	Estimate
0039-17-167	Pharr	Hidalgo	US 83	$10,000,000
932-01-098	Beaumont	Jefferson	FM 365	$12,000,000
932-01-076	Beaumont	Jefferson	FM 365	$7,456,610
0014-08-075	Waco	McLennan	IH35	$117,910,000
3097-02-900	Pharr	Hidalgo	FM 396	$11,000,000
5 Projects				**$158,366,610**

Under the unemployment criterion, about 12% of projects by dollar volume qualify as EDA projects.

5.5.3 Texas per Capita Income Rates 2008

Criterion for EDA qualification: Per capita income 80% or less than national average. The latest year for which per capita income data is available from the Census Bureau is 2008. The Bureau of Economic Analysis (BEA) reported the average U.S. per capita income in 2008 as $40,208 (BEA SA1-3 Per capita personal income). However, the Census Bureau data is a sampling of counties, and 2008 per capita income is only available for 117 of the 254 counties in Texas. The following chart shows those of the 117 Texas counties that had an average 2008 per capita income of 80% (=$32,166) or less of the national average.



Source: Census Bureau

Figure 5.3: Texas counties qualifying as EDA: Average per capita income in 2008 equal to or less than $32,166

Table 5.4: List of "Plan B" projects qualifying by 2008 per capita income

CSJ	District	County	Highway	Estimate
020507043	TYL	Anderson	US79	$31,408,562
0187-03-051	YKM	Austin	SH 36	$14,100,000
018702055	YKM	Austin	SH36	$14,700,000
0187-02-055	YKM	Austin	SH 36	$21,500,000
0072-12-179	SAT	Bexar	IH 10	$11,772,609
0915-12-978	SAT	Bexar	SS 345	$18,000,000
0072-08-120	SAT	Bexar	IH 10	$27,808,589
0915-12-224	SAT	Bexar	MH	$32,000,000
8000-15-012	SAT	Bexar	CS	$33,000,000
2105-01-038	HOU	Brazoria	FM 2234	$2,857,153
2105-02-003	HOU	Brazoria	FM 2234	$14,962,907
0117-02-028	BRY	Brazos	SH 21	$27,439,394
0252-02-046	AUS	Burnet	US 281	$30,141,608
1024-01-042	BMT	Chambers	FM 565	$5,566,899
019402087	WFS	Cooke	IH35	$12,000,000
235001043	WAC	Coryell	US190	$22,605,440
0264-07-029	AMA	Dallam	VA	$8,273,273
2121-04-906	ELP	El Paso	IH 10	$102,000,000
004804079	DAL	Ellis	IH35E	$152,000,000
1683-01-034	HOU	Fort Bend	FM 1640	$5,433,635
2093-01-009	HOU	Fort Bend	FM 2218	$12,400,000
0089-09-068	HOU	Fort Bend	US 59	$16,000,000
0039-17-167	PAR	Grayson	US75	$1,134,000
004519041	PAR	Grayson	US82	$9,300,000
090939114	HOU	Harris	SH 146	$5,408,461
3050-03-012	HOU	Harris	FM 2978	$8,295,117
8170-12-006	HOU	Harris	Hempstead	$9,540,800
0271-06-110	HOU	Harris	IH 10	$30,250,000
0271-07-242	HOU	Harris	IH 10	$57,438,000
0005-14-067	PHR	Hidalgo	US 83	$10,000,000
3097-02-900	PHR	Hidalgo	FM 396	$11,000,000
185-40-1031	LFK	Houston	LP 304	$4,251,688

CSJ	District	County	Highway	Estimate
932-01-076	BMT	Jefferson	FM 365	$7,456,610
932-01-098	BMT	Jefferson	FM 365	$12,000,000
278601010	BWD	Lampasas	FM2657	$3,198,655
0006-06-904	LBB	Lubbock	Slide Rd	$0
001408075	WAC	McLennan	IH35	$117,910,000
0005-14-067	ODA	Midland	IH 20	$21,499,826
0675-08-084	HOU	Montgomery	IH 45	$50,172,000
0675-08-061	HOU	Montgomery	IH 45	$12,022,200
0074-06-202	CRP	Nueces	IH 37	$9,545,344
1069-01-028	CRP	Nueces	SH 357	$10,000,000
004718902	ATL	Panola	SH149	$17,822,900
000912073	DAL	Rockwall	IH30	$23,853,795
133002034	FTW	Tarrant	FM1187	$11,083,759
017209031	FTW	Tarrant	US287	$13,337,137
036301000	FTW	Tarrant	SH26	$16,229,049
197801048	FTW	Tarrant	FM1938	$19,286,021
036301114	FTW	Tarrant	SH26	$33,671,000
0389-13-052	ABL	Taylor	IH 20	$10,000,000
0063-11-042	SJT	Tom Green	SL 306	$10,923,850
0015-08-116	AUS	Travis	IH 35	$7,000,000
2121-04-906	YKM	Victoria	LP463	$10,995,889
271801009	AUS	Williamson	RM2769	$3,400,000
900114901	AUS	Williamson	US183A	$108,000,000
55 Projects		**TOTALS**		**$1,291,996,170**

Under the per capita income criterion, about 96% of projects by dollar volume qualify as EDA projects. The five projects that qualified under the unemployment criterion also qualify under this criterion, so the above list gives all the projects that qualify under both criteria.

5.5.4 EDA-qualified counties and projects

The following chart shows the counties that qualify under the two primary criteria, namely, unemployment and per capita income.

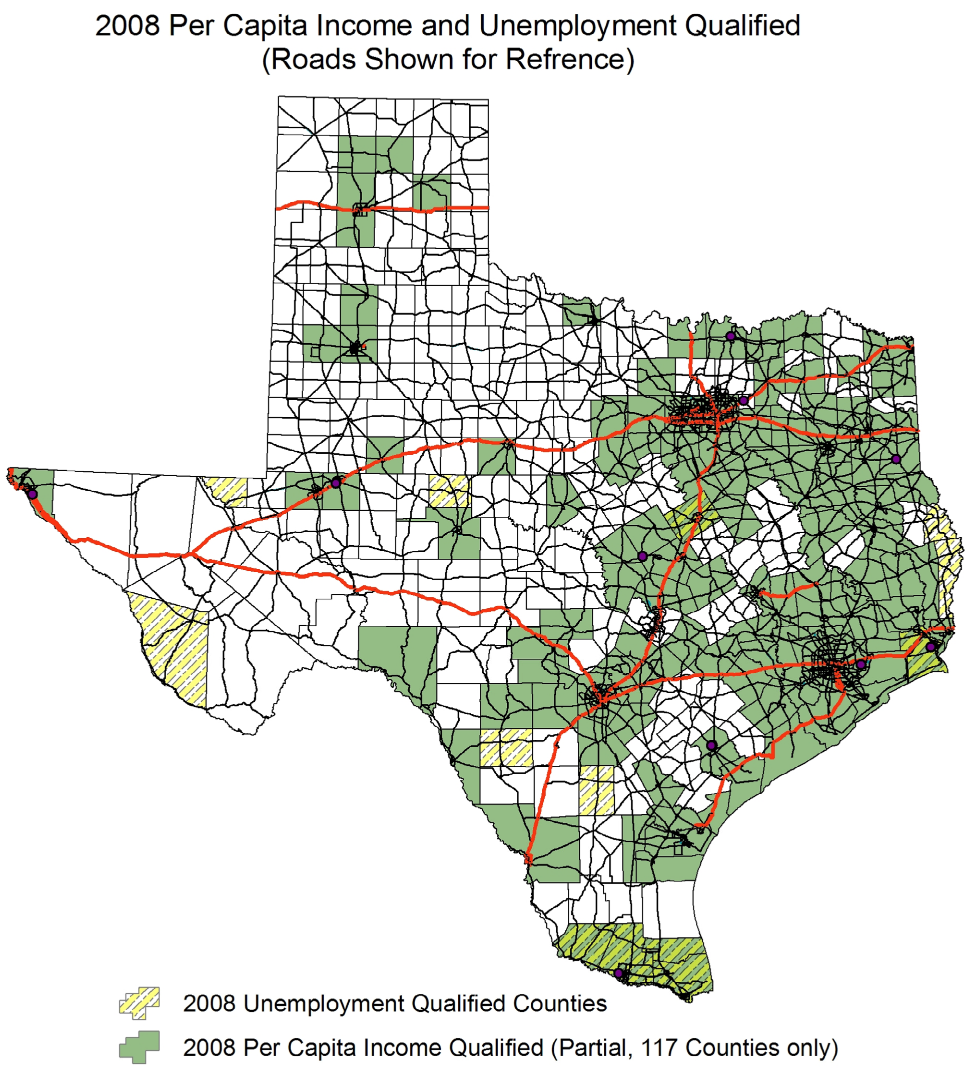


Figure 5.4: Texas counties qualifying as EDA: Average per capita income in 2008 equal to or less than $32,166

The projects that do not qualify under either criterion with available data are listed in the next table. *Note that they may be in counties for which per capita income data was not available.*

Table 5.5: List of "Plan B" projects not qualifying as EDA

CSJ	District	County	Highway	Estimate	
2469-01-007	SJT	Kimble	FM 2169	$3,000,000	
0132-03-900	CHS	King	US 82/SH 114	$5,067,845	
0133-01-905	CHS	King	US 82/SH 114	$5,400,000	
0902-02-035	AMA	Potter	VA	$8,273,273	
0463-06-024	ODA	Winkler/Ector	SH 302	$2,175,346	Project LET

5.6 Conclusion

Under ARRA unemployment and per capita income criteria for EDA, 96% by dollar volume of Plan B projects are located in economically distressed areas of Texas.

Texas unemployment data is available from numerous sources. Because different sources use different methods of computation, it was decided to use data from the U.S. Bureau of Labor Statistics (BLS). The latest year for which BLS data is fully available is 2008. Data for several months in 2009 are also available, but because each month is a sampling, all the counties of Texas are not covered. Also, data may be adjusted or unadjusted, creating inconsistency. BLS unemployment data for 2008 was used to identify 13 counties that had an unemployment rate 1% or greater than the 2008 national average of 5.8%. By this method, only 5 Plan B projects with a total estimate of $158 million qualify under the ARRA unemployment criterion.

Texas per capita income data is also available from numerous sources. Again, because different sources use different methods of computation, it was decided to use data from a national source, the U.S. Census Bureau. To maintain consistency with the unemployment analysis, Census data for 2008 was used. Data for several months in 2009 are also available, but because the Census Bureau only does partial sampling, 2008 data for only 117 of 254 counties is available. Census per capita income data for 2008 was used to identify counties that had a per capita income 80% or less than the 2008 national average of $40,208. By this method, 55 Plan B projects with a total estimate of $1,292 million qualify under the ARRA unemployment criterion, 96% of the total Plan B program of $1,345 million.

Given that, for this task, data sources had to be nationally sourced and had to be consistent across the state and across a time period within the last 2 years, and that <u>almost all Plan B projects qualify as EDA</u>, it was not necessary to delve for data at a sub-county level or under the ARRA Special Needs criteria. If a similar analysis such as this is needed for another set of projects, CTR can endeavor to acquire the necessary data.

5.7 Data Sources

1. 2008 national unemployment rate: 5.8% (BLS, Texas Workforce Commission)
2. 2007 national unemployment rate: 4.6% (BLS, Texas Workforce Commission)
3. 2008 Texas county unemployment rates (BLS, Texas Workforce Commission)
4. 2008 national per capita income: $40,208 (BEA SA1-3 Per capita personal income)
5. 2007 national per capita income: $38,615 (BEA CA1-3 Per capita income)
6. 2008 Texas county per capita income (Census Bureau 2006–2008 American Community Survey 3-Year Estimates—117 counties)
7. 2007 Texas county per capita income (BEA CA1-3 Per capita personal income)

Chapter 6. Dallas District IH 30 Noise Project

6.1 Introduction

Task 10: Dallas District IH 30 Noise Project

The objective of this task was to examine claims of excessive noise on a section of IH 30 in West Dallas through field measurements and resident interviews, and to identify potential mitigation measures including noise wall treatments and porous friction course (PFC) overlays.

6.2 Results

The following is a summary of work completed as of July 2010 on this task. Additional work was requested by the Dallas District Engineer, and is the subject of a new work task for FY 2011.

Memorandum on IH 30 Noise Project
July 2010

6.3 Overview

This chapter summarizes a discussion at the Dallas District on July 14, 2010. The purpose of the meeting was to outline an approach to building and testing an experimental absorptive wall on the westbound side of IH-30 extending an indefinite length eastward from Fort Worth Avenue. The wall is to be constructed by adding absorptive material to the existing concrete retaining wall, the objective of which is to reduce reflected noise reaching the residences to the south of the highway.

A proposal was prepared by Sound Fighter Systems (SFS) suggesting two walls from Sylvan to Hampton at an estimated cost of $1.9 million. Much of the discussion centered on the possibility of building a shorter section for experimental purposes, and how that shorter section might be specified to allow meaningful before and after measurements that would allow some degree of confidence regarding the predicted performance of the proposed larger structure.

The PFC overlay currently being laid down on IH 30 nearby was also discussed in terms of how to test how to measure the noise reduction benefit afforded the Kessler Park neighborhood south of the project.

6.4 PFC Overlay

As of the time this memo is being prepared, a new, thin PFC overlay is being placed on IH30 near Sylvan Ave. The researchers expect significant noise reduction in the Kessler Park neighborhood from this measure alone as an adjacent section on IH30 was monitored and studied under TxDOT Research Project 0-5185 in 2006. Before and after measurements on that section as it changed from a tined continuously reinforced concrete pavement (CRCP) surface to a PFC surface exhibited a 3dBA overall noise reduction (equivalent to halving the traffic) and a stunning 10dBA reduction at the particularly objectionable 1kHz frequency caused by the CRCP tine spacing (Figure 6.1). Because the noise measured in the Kessler neighborhood is predominantly a “whine,” it’s expected the PFC overlay alone will greatly reduce the perceived noise at that location.

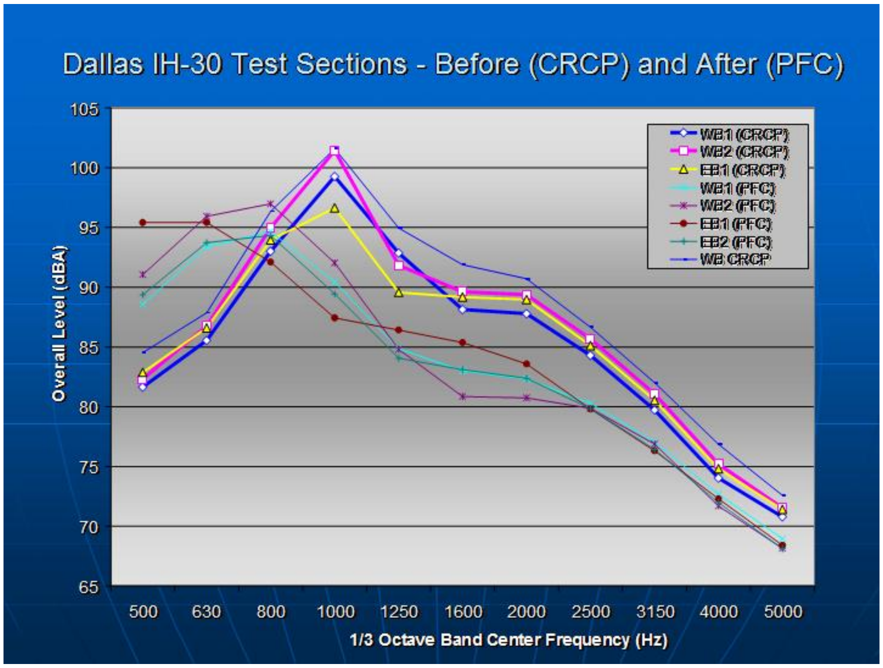


Figure 6.1: Before and after OBSI measurements on PFC overlay, IH-30 2006

However, recent OBSI measurements (2010) on the 2006 overlay indicate that it may have closed up and is no longer providing any significant noise reduction vs. conventional asphalt (Figures 6.2 and 6.3). This is something to consider for long term noise mitigation.

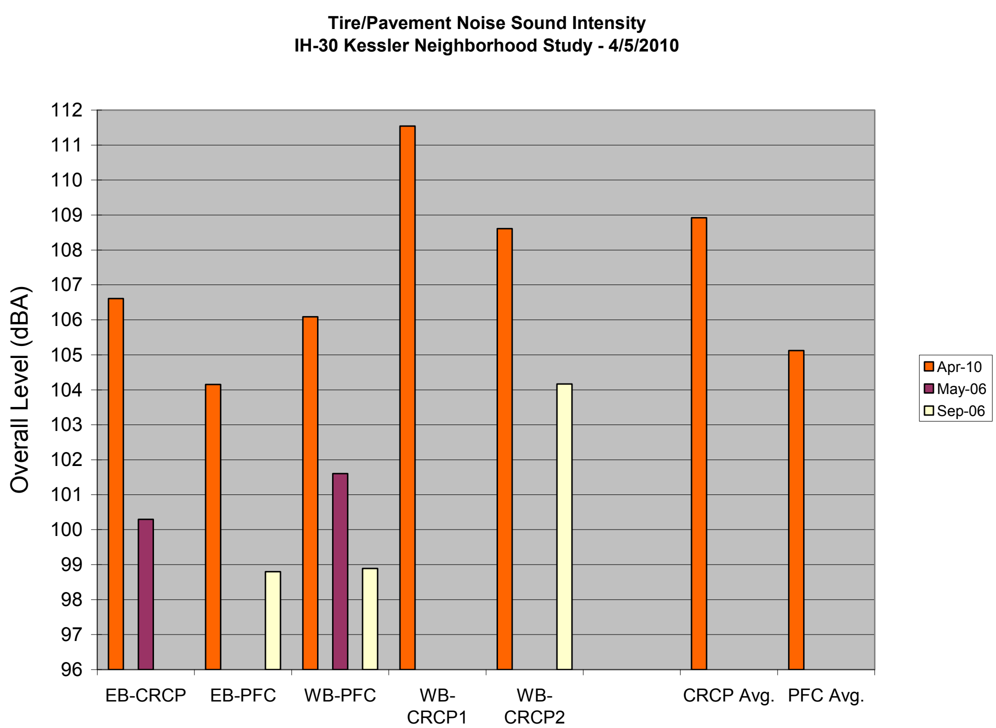


Figure 6.2: Deterioration of noise absorption on IH30 PFC overlay, 2006–2010

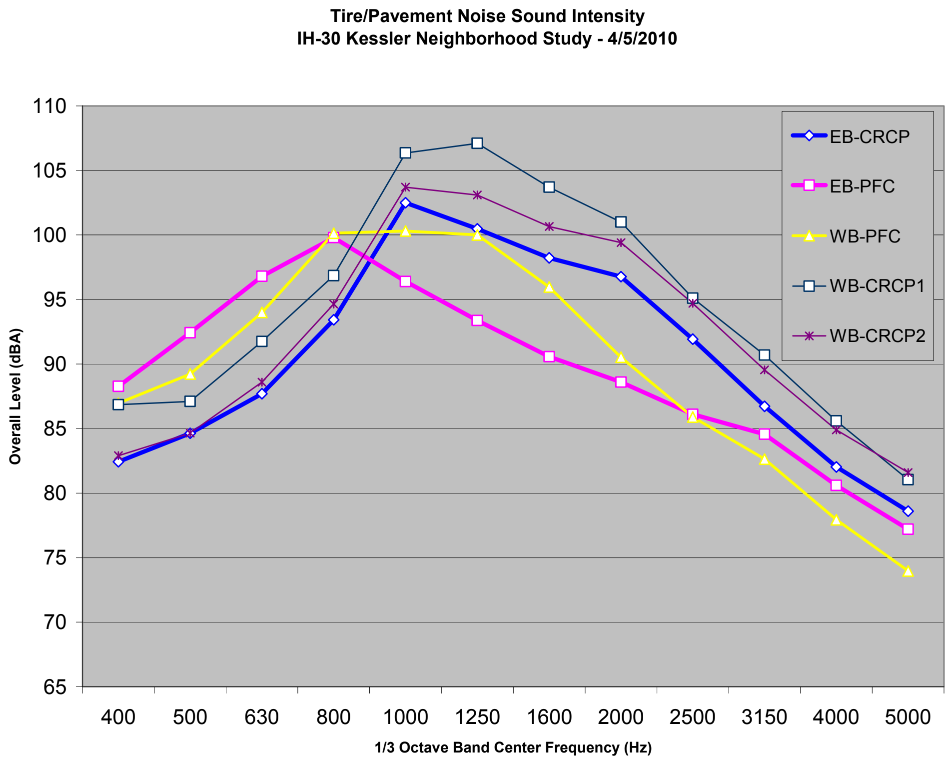


Figure 6.3: Shift of noise spectrum on WB PFC section, April 2010

In any case, the PFC is going in now and its noise reduction efficacy will be measured at the tire/pavement interface using the On-Board Sound Intensity (OBSI) method, and in the Kessler neighborhood using sound pressure level (SPL) meters according to the International Electrotechnical Commission (IEC) standard protocol measuring Leq (the equivalent continuous sound level). Baseline (before) measurements have already been taken for comparison.

There is an issue with the test vehicle tire condition during the measurements shown in Figure 6.3, a concern that aging of the tire has increased the noise levels slightly. However, if this is the case, then the eastbound PFC would also show that increase in Figure 6.3 and it does not. Therefore it appears the noise increase is real and quite significant, especially because the spectrum is shifted into the "whine" area typical of CRCP and matches the tonality observed in the Kessler neighborhood.

Because that section is not part of the new overlay, it will be retested shortly using a new tire, conclusively resolving the issue. Wayside measurements (including traffic count, classification, and speed) were also taken and are being processed.

6.5 Length of the Absorptive Wall

Most of the meeting focused on the possibility of applying the absorptive material on a shorter section than proposed by SFS, in order to reduce cost but still retain the ability to make meaningful measurements that can be used to predict the performance of a larger wall. The original length suggested by the researchers was 0.2 mi (1,056 ft), whereas the SFS proposal specifies a 2,600 ft wall. This is understandable on their part, as it reduces the noise reflections from the remaining untreated wall by increasing the distance to the receivers. Figure 6.4 shows the concept.

Figure 6.4: Proposed treatment area and difficulty of testing a shorter area

The red line shows the proposed SFS wall, and the face is where a residence might be. The right side arrow shows how far reflected noise would have to travel to reach the receiver, vs. the white arrow indicating the much shorter distance reflected sound would travel from a shorter, test wall. With the 2,600 ft wall as proposed, the reflected noise from the right side would be negligible. With the shortened wall, it would likely be quite significant, reducing the ability to determine the efficacy of the absorptive treatment.

The solution to this problem is to move the measurement location as close to the center of the wall and toward the highway as practically possible. Rather than just guess the best locations for wayside measurement, it's proposed to use the FHWA-approved Traffic Noise Model (TNM) to predict a noise contour map showing the area that applying the absorptive material will affect. TNM allows specifying NRC (noise reduction coefficient) numbers for the wall, so the suggested NRC values from SFS can be used as a starting point.

TNM will then tell us where to measure with a specified confidence, and thereby how short the wall can be built to give us the numbers we need.

After the short wall is constructed, wayside measurements will be taken to determine the as-built NRC numbers, and to validate the TNM predictions, giving us confidence to proceed constructing the larger, more expensive wall, if needed. Hopefully, the measured (as-built) NRC numbers will be similar to the manufacturer's specs, giving additional confidence.

6.6 Field Visits to Existing SFS and Carsonite Projects

Another confidence building approach discussed at the meeting was the idea of visiting and measuring the performance of SFS and Carsonite products at sites where they've already been installed. As-built before and after performance data seems to be unavailable for both products, but there is an approach that can be used to get a fairly accurate idea of how well the products actually perform in service.

The closest finished projects for SFS and Carsonite are in Shreveport, LA, and Houston, TX, respectively. Though there is no wayside test data for the before condition on these projects, the researchers propose traveling to both projects to collect OBSI and wayside noise data, along with the necessary geometric and traffic data required to support an accurate TNM analysis. TNM would then be used to predict the wayside noise that should be present at the observed traffic levels for a simple concrete barrier and for the unconventional barriers using the manufacturers' NRC values. The predictions for the absorptive barriers should approximately match, and the difference in the observed values from the concrete wall predictions would give the "delta" or as-built noise reductions afforded by the SFS and Carsonite walls.

This step would afford additional confidence (or warning) going forward on the Kessler project.

6.7 Economic Analysis

After the TNM analysis has determined the minimum wall length that must be built to properly test the material, an economic analysis would be conducted to determine the optimal treatment area (length and height) that will be testable with good confidence, yet within the suggested budget of $100,000 mentioned at the meeting. The proposed solution would then be discussed with the two manufacturers to determine if their concerns would be accommodated (e.g., their understandable desire to not have the pilot project fail due to insufficient treatment area).

6.8 Performance or Warranty Spec

Another idea suggested at the meeting was the use of a performance or warranty spec, as opposed to the method spec the current plan essentially is. Specifically, a performance spec would provide financial incentives and/or disincentives to the manufacturer based on the as-built performance of the treatment. If the manufacturers really have the confidence in their product they've been expressing, then it is possible some minimum dB reduction at a specified distance from the roadside could be agreed upon, which then must be met in order for full payment to be made. This is similar to some pavement construction contracts, possibly some used by Dallas District in the past. In a nutshell, it would simply share the risk between TxDOT and the manufacturer, and be a concrete indication of the manufacturer's confidence in their product.

A warranty spec simply takes the performance spec a bit farther, assuring performance over time. In the case of sound absorption, it's somewhat less important than in pavement (pavement performance over time is more difficult to predict from after construction measurements) but would provide some protection against the absorptive material deteriorating rapidly.

6.9 Time Line

A detailed schedule of work will be prepared after this approach is discussed and finalized, but the sequence of work as described above would be as follows:

(1) Test noise levels (OBSI and wayside) after new PFC is down. Noise wall improvement may not be necessary (from an engineering standpoint, politics aside).

(2) Perform "before" analysis of IH30 project, predicting noise reduction contours using the NRC values given by the manufacturers.

(3) Use results in conjunction with economic analysis to determine the size of the experimental treatment area, starting from Fort Worth Ave bridge and proceeding eastward, as well as to determine the measurement locations inside the predicted noise reduction contours.

(4) Visit the existing sites in Houston and Shreveport to measure as built effectiveness of those treatments.

(5) Assuming a go decision on the short experiment, with or without performance spec agreement from the manufacturers, build the short wall.

(6) Measure the as-built effectiveness of the short wall treatment, at the receiver locations determined by the TNM analysis, and compare observed to predicted.

(7) Use all sources of information described above to determine whether the treatment will be expanded to the larger area.

6.10 Summary

It is very likely that the PFC overlay now being placed will greatly reduce the objectionable noise at the Kessler residences, which consist almost entirely of the CRCP type whine that a PFC overlay is certain to eliminate; how long that reduction will last, especially with a thin overlay, is questionable.

If unconventional noise absorption is to be tested based on engineering concerns, there are much better choices than the IH30 site, due to the difficult geometry and expense of construction. However, using TNM modeling, it will likely be possible to effectively test there despite the difficulty, by carefully choosing the wall length and the receiver test locations. Measuring the SFS and Carsonite projects in Shreveport and Houston will give additional confidence. Using all those data sources, then, later, measured performance from the small, initial experiment, TNM can be relied on to give a reasonably accurate prediction of what to expect from the full area treatment, should a decision be made to go forward with that.

A performance spec agreement with the manufacturer, if such can be had, will further minimize the risk to TxDOT.

Chapter 7. Interim Report on Statistical Analysis of TxCAP and Its Subsystems

7.1 Introduction

Task 11: Statistical Analysis of TxCAP and its Subsystems

The objective of this task was to conduct statistical analyses of the data used by TxDOT to develop Texas Condition Assessment Program (TxCAP) scores, to help in deciding if the difference between two TxCAP scores is a true difference (i.e., statistically significant) or a measurement error.

7.2 Results

The following is a summary of work completed as of August 2010 on this task. This task has been extended into FY 2011.

7.2.1 Introduction: Texas Condition Assessment Program (TxCAP)

Currently, TxDOT uses TxCAP that is composed of three subsystems to measure and compare the overall road inventory condition among its 25 Districts. The three subsystems are the Pavement Management Information System (PMIS), which is an automated system for storing, retrieving, analyzing, and reporting pavement condition information; the Texas Maintenance Assessment Program (TxMAP), which is a manual, visual condition survey that documents the overall maintenance condition of the state highway system; and the Texas Traffic Assessment Program (TxTAP), which evaluates the department's progress in the consistency, quality, and uniformity of traffic control devices on the state highway system. TxCAP combines information from PMIS, TxMAP, and TxTAP to get an overall picture of state roads.

7.2.2 Problem Definition

TxCAP provides a comprehensive assessment of the Interstate and Non-Interstate highway system. However, the scores for each of the subsystems are based on data of different sample sizes, accuracy, and levels of variations, making it difficult to decide if the difference between two TxCAP scores is a true difference or a measurement error. In order to determine if the difference between two TxCAP scores is a true difference (i.e., statistically significant), statistical analyses of the data used to develop the TxCAP scores have to be conducted.

7.2.3 Research Objectives

This research objectives are to 1) determine if enough data is provided in the sample size and the patterns revealed through analysis of the data collected; 2) determine the current level of statistical significance of the current TxCAP system by analyzing the current sample size and level of statistical significance of the sub-systems (PMIS, TxMAP and TxTAP); and 3) provide the recommended sample size of the TxCAP system including the sub-systems with reasonable estimates of the likely levels of variance in the data from pre-existing data.

At the end this research, a comprehensive report will be delivered completely documenting all work performed, method(s) used, results achieved, and recommendations on improvements to the current scoring system of TxCAP and its subsystems.

7.2.4 Methodology

How to Determine the Sample Size

It is a generally recognized statistical rule that the accuracy of the estimated mean value of a population increases as the number of samples taken from the population measured also increases. The accuracy of the estimate for variability or standard deviation from the mean also increases with the increase in sample size. In other words, the greater the number of sampling conducted, the higher the confidence level that the mean will be identified with sufficient accuracy and that the variability will be better defined.

Type I Error

Type I error, usually denoted as α, is the probability of rejecting a null hypothesis when it is actually true. Plainly speaking, it occurs when we are observing a difference when in truth there is none, thus indicating a test of poor specificity. Type I error can be viewed as the error of excessive credulity.

Type II Error (Power of Statistical Test)

Type II error, usually denoted as β, is the probability of failing to reject a null hypothesis when it is in fact not true. In other words, this is the error of failing to observe a difference when in truth there is one, thus indicating a test of poor sensitivity. Type II error can be viewed as the error of excessive skepticism.

The power of a statistical test, usually denoted as $1-\beta$, is the probability that the test will reject the null hypothesis when the alternative hypothesis is true (i.e., the probability of not making a Type II error). As the power increases, the chances of a Type II error decreases.

Required Sample Sizes for Hypothesis Tests

A common problem facing statisticians is calculating the sample size required to yield a certain power for a test, given a predetermined Type I error α. A typical example for this is as follows:

Let X_i, i = 1, 2, ..., n be independent observations taken from a normal distribution with unknown mean μ and known variance σ^2. Let us consider two hypotheses, a null hypothesis:

$$H_0: \mu = 0$$

and an alternative hypothesis:

$$H_\alpha: \mu = e$$

for some smallest significant difference e >0. This is the smallest value for which we care about observing a difference. Now, if we wish to (1) reject H_0 with a probability of at least $1-\beta$ when $H_\alpha$is true (i.e., a power of $1-\beta$), and (2) reject H_0 with probability α when H_0 is true, then we need the following:

If z_α is the upper α percentage point of the standard normal distribution, then α can be expressed as

$$P\left(\bar{x} > z_\alpha \sigma/\sqrt{n} | H_0 \text{ true}\right) = \alpha$$

and so reject H_0 if the sample average $\bar{x}$ is more than $z_\alpha \sigma/\sqrt{n}$, which is a decision rule that satisfies (2). (Note: this is a one-tailed test.)

In order to satisfy (1) when H_α is true, the following relationship is required

$$P\left(\bar{x} > z_\alpha \sigma/\sqrt{n} | H_\alpha \text{ true}\right) \geq 1 - \beta$$

Through careful manipulation, this can be shown to happen when

$$n \geq \left(\frac{\Phi^{-1}(1-\beta) + z_\alpha}{\frac{\mu^*}{\sigma}}\right)^2$$

where Φ is the normal cumulative distribution function. Generally, two approaches can be adopted to calculate the sample size using the results above. One is to control the Type I error only and the other is to control both the Type I and Type II errors.

Controlling Type I Error

When only the Type I error is concerned, the following three steps should be carried out to calculate the desired sample size.

1. Specify the Tolerable Error

The engineer must determine the level of precision needed. The desired precision is often expressed by probability in absolute terms, as

$$P\left(|\bar{y} - \bar{y}_\mu| \leq e\right) = 1 - \alpha$$

where,

$\bar{y}$ = sample mean;

$\bar{y}_\mu$ = population mean;

α = type I error;

e = tolerable error

The engineer must select a reasonable value for α (type I error or producer's risk) and e, which is called the margin of error or tolerable error. To achieve the desired relative precision, the precision may be expressed as

$$P\left(\left|\frac{\bar{y} - \bar{y}_\mu}{\bar{y}_\mu}\right| \leq e\right) = 1 - \alpha$$

2. Find an Equation Relating the Sample Size *n*

The simplest equation relating the precision and sample size comes from the confidence interval. To obtain absolute precision, find a value of n that satisfies

$$e = \frac{Z_{\alpha/2}\sigma}{\sqrt{n}}$$

Solving for n , it has

$$n = \frac{\left(Z_{\alpha/2}\right)^2 \sigma^2}{e^2}$$

where:
n = sample size
$Z_{\alpha/2}$ = the $(1 - \alpha/2)$th percentile of the standard normal distribution
σ = standard deviation
e = tolerable error

3. Adjust the Sample Size *n*

The equations presented before are based on asymptotic theory (as the sample size goes to infinity); therefore, the sample size n should be adjusted for a n that is not infinite.

$$n_\alpha = \frac{n}{1 + n/N}$$

where
n_α = adjusted sample size
n = the sample size that ignores the finite population correction (FPC)
N = population size

Controlling Both Type I Error and Type II Error

When both the Type I and Type II error are concerned, the following steps should be taken to obtain the sample size.

Calculating Type II Error Probability

Calculating β can be very difficult for some statistical tests, but the Z test can be used to demonstrate both the calculation of β and the logic employed in selecting the sample size for a test.

For the test of $H_0: \mu = \mu_0$ against $H_a: \mu < \mu_0$, it is only possible to calculate type II error probabilities for any specific point in H_a. Suppose $\mu = \mu_0 - e$. The power of this test can be expressed as

$$1 - \beta = P(\bar{X} < a, \text{when } \mu = \mu_0 - e)$$

The probability of a type II error, β, is

$$\beta = P(\bar{X} > a, \text{when } \mu_a = \mu_0 - e)$$

$$\beta = P\left(\frac{\bar{X} - (\mu_0 - e)}{\sigma/\sqrt{n}} > \frac{\bar{X} - (\mu_0 - e)}{\sigma/\sqrt{n}},\ \text{when } \mu_a = \mu_0 - e\right)$$

where, $\frac{\bar{X}-(\mu_0-e)}{\sigma/\sqrt{n}} = Z$. Therefore, μ_a has an approximately standard normal distribution and the probability β can be determined by finding an area under a standard normal curve.

Find an Equation Relating the Sample Size n

Suppose the test is $H_0: \mu = \mu_0$ against $H_a: \mu < \mu_0$. If the desired value of α and β is specified, the sample size for controlling both type I error and type II error can be expressed as

$$n = \frac{(Z_\alpha + Z_\beta)^2 \sigma^2}{e^2}$$

where,
n = sample size
α = type I error
β = type II error
Z_α = the $(1-\alpha)$th percentile of the standard normal distribution
Z_β = the $(1-\beta)$th percentile of the standard normal distribution
σ = standard deviation
e = tolerable error

Sample Size of Each Subsystems (PMIS, TxMAP, TxTAP) Given β, α and e

From the discussion earlier, we see that the sample size is a function of the Type I error α, the power of the test $1-\beta$, the tolerable error e, and the standard deviation σ. The value of α directly affects the confidence level. We see that higher the confidence level, the larger is the required sample. For a fixed value of α and holding other parameters constant, the larger the type II error β the smaller is the required sample size. The required sample size n is proportional to the square of standard deviation σ. Thus for samples with large variability in the PMIS, TxTAP or TxMAP scores, a larger sample size is required to obtain a result with a fixed confidence level and power. The required sample size n is inversely proportional to the square of tolerable error e, i.e., if the allowable error is decided to be kept small; the required sample size is larger and increases in the order of square of the decrease of e.

7.3 Comparison of TxCAP Scores

In this section, we discuss how to compare two TxCAP scores and how to decide if they are significantly different from each other. There are two methods available: the t-test and the standard deviation method.

7.3.1 Method 1: t-test (Compare Means from Two Different Samples)

Calculate the TxCAP (Mean, Standard Deviation) for Each District

The TxCAP score for each district is calculated from its components (PMIS, TxMAP, and TxTAP) scores using the following formula:

$$\text{TxCAP} = (0.5 \times \text{PMIS}) + (0.25 \times \text{TxMAP}) + (0.25 \times \text{TxTAP})$$

The PMIS, TxMAP, and TxTAP scores are calculated for each district for each year. From this we can calculate the TxCAP score for each district for each year. The mean value of the TxCAP scores can then calculated for each of the districts.

The standard deviation of the mean TxCAP score for each district is then calculated using the following formula:

$$s_{\mathrm{TxCAP}} = \sqrt{(0.5^2 \times s^2_{\mathrm{PMIS}}) + (0.25^2 \times s^2_{\mathrm{TxMAP}}) + (0.25^2 \times s^2_{\mathrm{TxTAP}})}$$

where,
s^2_{PMIS} = the variance of the PMIS score
s^2_{TxMAP} = the variance of the TxMAP score
s^2_{TxTAP}= the variance of the TxTAP score

Compare the TxCAP between Two Districts by Using the t-test

This test is used when the two population variances are assumed to be different (the two sample sizes may or may not be equal) and hence must be estimated separately. The *t*-statistic to test whether the population means are different can be calculated as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{X}_1 - \bar{X}_2}}$$

where,
$\bar{X}_1$ = the mean TxCAP score of one district;
$\bar{X}_2$ = the mean TxCAP score of another district and

$$s_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

where, s^2 is the unbiased estimator of the variance of each of the two samples, n = sample size. The Degrees of freedom is calculated using

$$\mathrm{D.F.} = \frac{\left(s_1^2/n_1 + s_2^2/n_2\right)^2}{\left(s_1^2/n_1\right)^2/(n_1 - 1) + \left(s_2^2/n_2\right)^2/(n_2 - 1)}$$

7.3.2 Method 2: Standard Deviation Method

Calculate the TxCAP (Standard Deviation of the Sample Mean) for All 25 Districts Together

The mean value of the TxCAP scores for all 25 districts is calculated as above using the formula

$$\mathrm{TxCAP} = (0.5 \times \mathrm{PMIS}) + (0.25 \times \mathrm{TxMAP}) + (0.25 \times \mathrm{TxTAP})$$

The standard deviation of the sample mean is then calculated. The standard deviation is the square root of the variance and is calculated using the following formula:

$$s_{\text{TxCAP}} = \sqrt{(0.5^2 \times s_{\text{PMIS}}^2) + (0.25^2 \times s_{\text{TxMAP}}^2) + (0.25^2 \times s_{\text{TxTAP}}^2)}$$

where,
s_{PMIS}^2 = the variance of the PMIS score
s_{TxMAP}^2 = the variance of the TxMAP score
s_{TxTAP}^2= the variance of the TxTAP score

7.3.3 Decide if Two Scores are Different by Using the Standard Deviation

If the difference between two means is larger than two standard deviations of the sample mean, then the difference is significant at the 95% confidence level. If the difference between two means is lesser than two standard deviations of the sample mean, there is no significant difference between the means at the 95% confidence level.

7.4 Case Study

The statistical analysis of TxCAP in particular involves determining if two particular TxCAP scores are statistically different. The TxCAP scores may be from different areas for the same period or across different time periods for a specific area (either a particular district or the entire state). The analysis is carried on a sample data set spanning over a period of three years.

7.4.1 Data Description

The TxCAP score is calculated from the scores of the three subsystems, i.e., the TxTAP score, the TxMAP score, and the PMIS score. Each of these scores is the calculated as the weighted average of the component scores. Each component score is the weighted average of element scores. The element/features are scored manually by experts and technicians through field inspections. The components of the subsystems are detailed in Figure 7.1.

These components may consist of single or multiple features/elements as shown in Table 7.1. For example, the components for calculating TxTAP are roadside signs, RR Xing, signals, shoulder texture, delineator, attenuator, stripping, and raised pavement marker. Roadside signs consist of the following elements: Approach Signing, Departure Signing, Sign Reflectivity, Breakaway, Sign Height, Lateral Placement, Message, and Panels. Each of these features is scored by means of a field survey. Currently the data is available only for the year 2007 for part of the TxTAP subsystem.

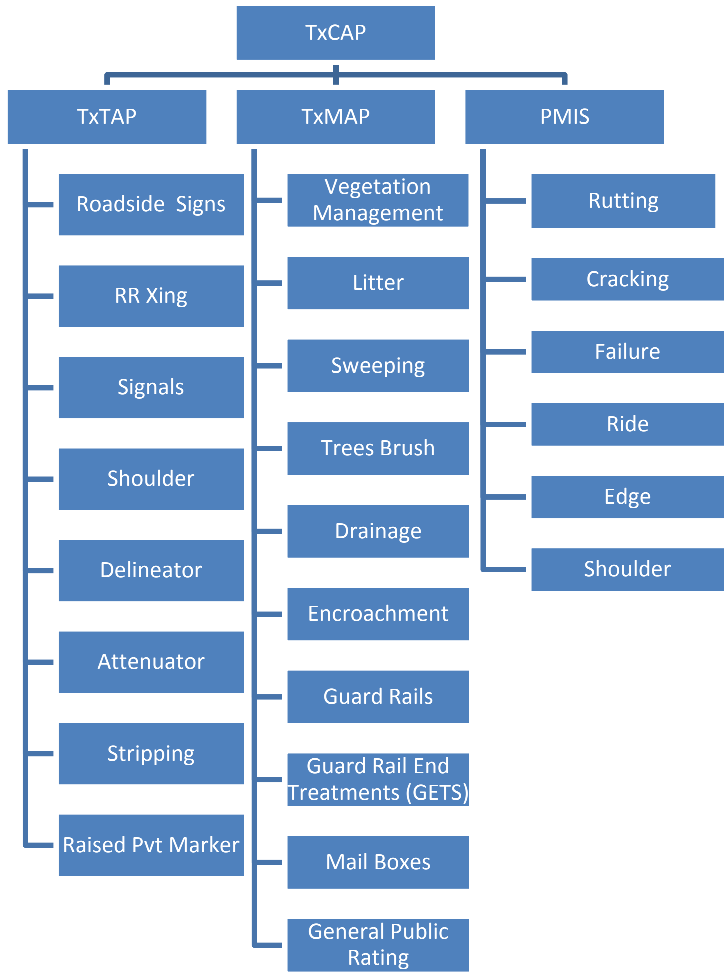


Figure 7.1: Breakdown of the TxCAP

Table 7.1: Elements of Components of TxTAP

Component of TxTAP	**Elements**
Roadside Signs	Approach Signing
	Departure Signing
	Sign Reflectivity
	Breakaway
	Sign Height
	Lateral Placement
	Message and Panels
RR Xing	Warning Signs
	Pavement Markings
Signals	Signal Operation
	Signal Faces
	Pedestrian Elements
	Maintenance

7.4.2 Sample Size Calculation

Controlling Type I Error

Hypothesis testing and decision errors are crucial concepts in determining sample size. When testing these hypotheses there are two possible sources of errors, namely Type I error and Type II error. In many instances the Type I error is considered only. The probability of Type I error is denoted by α and is also known as the level of significance. In this case study we aim to control both Type I and Type II error when determining an acceptable sample size. Therefore we will use the methods described in the next section.

Sample Size When Type I and Type II Error Are Controlled

As mentioned in the previous section, that there are two types of error related to hypothesis testing when determining sample size. In this case study we aim to control both types of error in determining a suitable sample size. The sample size calculation of the elements/features of the components of TxTAP is shown in the following tables. The calculations are carried over a range of values of α and β. Different values of the tolerable have been mentioned in literature and are determined in most cases by expert judgment. To demonstrate the calculation of sample size, we are taking the tolerable error to be one standard deviation of the distribution of the scores of that particular element. The formula for calculating sample size considering both types of error is

$$n = \frac{\left(Z_{\alpha/2} + Z_{\beta}\right)^2 \sigma^2}{e^2}$$

Because the tolerable error (e) is taken equal to the standard deviation (σ), the ratio of σ/e is equal to 1 and therefore the sample size depends only on the values of α and β and becomes independent of element. The variations in sample size with different values of the two types of errors are shown in Table 7.2.

Table 7.2: Sample Sizes With Type I And Type II Error

			Sample Sizes						
Sig. level, α	**confidence level**	**β =**	**0.01**	**0.05**	**0.1**	**0.2**	**0.3**	**0.5**	**0.6**
1%	99%	σ/e = 1	22	16	13	10	8	5	4
3%	97%		18	12	10	7	6	4	3
5%	95%		16	11	9	6	5	3	2
10%	90%		13	9	7	5	3	2	1

The sample data collected for the year 2007 shows that different sample sizes we collected for the different elements. On average 21 data points were collected for the approach signing element. The average sample size collected (year 2007–2009) and sample size calculated (Table 7.2) for the various elements are shown in Table 7.3.

Table 7.3: Average number of data points collected under TxTAP

Element	**Average sample Size**	**Desired Sample Size ($\alpha = 0.01, \beta = 0.01$)**
Roadside Signs		
Approach Signing	21	22
Departure Signing	22	22
Sign Reflectivity	27	22
Breakaway	26	22
Sign Height	27	22
Lateral Placement	27	22
Message and Panels	27	22
RR Xing		
Warning Signs	4	22
Pavement Markings	4	22
Signals		
Signal Operation	5	22
Signal Faces	6	22
Pedestrian Elements	6	22
Maintenance	6	22

As can be seen in Table 7.3, the current practice of data collection allows us maintain a level of significance of 1% while maintaining a β value of 1% for the elements under the component roadside signs. However for RR Xing and Signals we need either relax the values of α and β or increase the sample size.

7.4.3 Comparing TxCAP Scores

There are two standard procedures for comparing between TxCAP scores: the t-test method and the standard deviation method. Each of these is detailed below. Because all the data is not currently available for calculate the TxCAP score, the following analysis is carried out on the TxTAP score. The methodology for comparing TxCAP and TxTAP are identical.

Using t-test

The t – test is used for comparing means of two different populations. Using t-test implies the TxCAP score for each district follows a different distribution. In the context of this case study, the individual TxCAP scores of a district can be used to calculate the variance of the TxCAP score for the district. Then the t-test can be used to determine if the difference between the TxCAP scores of two districts is statistically significant. However, due to the lack of enough

TxCAP data at this time, the analysis is not performed, but will be conducted when additional data is obtained.

Using Standard Deviation (When Comparing Sample Mean of TxCAP Scores of all 25 Districts)

One of the assumptions made when using the standard deviation method is that the TxCAP scores of all 25 districts form one distribution. Then it can be concluded that the mean score are statistically different when the difference of scores is greater than a multiple of the standard deviation of the TxCAP scores. Mathematically, this is expressed as:

If ($TxCAP_1 - TxCAP_2$) > c * (std dev), then the scores are statistically different
If ($TxCAP_1 - TxCAP_2$) < c * (std dev), then the scores are not statistically different
where c is a constant.

A sample calculation using TxTAP scores is presented. For the year 2007, the TxTAP scores for the Austin district and the Dallas district were 79.77 and 76.08 respectively and the standard deviation of the scores of the TxTAP scores for all 25 districts was 3.6 ($\sigma = 3.6$). When we consider c = 1 we find that the scores are statistically different. Table 7.4 shows the comparison of TxTAP scores between Austin and Dallas district using different values of c.

Table 7.4: Comparison of TxTAP Scores Using the Standard Deviation Method

$TxTAP_{Austin}$	$TxTAP_{Dallas}$	c	$c \times \sigma$	Remarks
79.77	76.08	1	3.6	Statistically Different
79.77	76.08	2	7.38	Not Different
79.77	76.08	3	10.8	Not Different

Assuming c to be 1 implies that proximately 68% of the difference between two TxTAP scores will be smaller than 3.6. Similarly, when c equals to 2 or 3, we are considering an acceptance region of 95% and 99% respectively. This implies that having a lower value of c will result in higher sensitivity, i.e., a smaller difference will be considered as a statistical difference.

Additional Data Requirement

In order to conduct a complete statistical analysis of TxCAP scores, we need additional data for the following data items.

<u>TxTAP Scores</u>

Field data of the following components and their corresponding elements are required (for the years 2007, 2008, and 2009), as shown in Table 7.5:

Table 7.5: Data required for components of TxTAP

Components of TxTAP	Elements
Shoulder Texture	As applicable
Delineator	
Attenuator	
Striping	
Raised Pvt Marker	

TxMAP Scores

Field data of the following components and their elements as shown in Table 7.6 are required for TxMAP:

Table 7.6: Data required for components of TxMAP

Components of TxMAP	Elements
Vegetation Management	As applicable
Litter	
Sweeping	
Trees and Brush	
Drainage	
Encroachments	
Guard Rails	
Guardrail End Treatments (GETS)	
Mail Boxes	
General Public Rating	

PMIS Scores

Field data of the following components and their elements as shown in Table 7.7 are required for PMIS:

Table 7.7: Data required for components of PMIS

Components of PMIS	Elements
Rutting	As applicable
Cracking	
Failure	
Ride	
Edge	
Shoulder	

Appendix A: Annual DOT Construction Programs in 1988 and 1998, and Increase in Consultant Involvement

	Annual construction Program ($million)		Annual consultant payments for PCE work ($million)		% Gain in payments from 1980 and from 1988	
State	**1988**	**1998**	**1988**	**1998**	**1988**	**1998**
Arizona		850	-	51		
Arkansas	200	380	1	18	90	1800
Colorado	144	300	43	45	108	-
Connecticut	350	400	50	25	14	(-42)
Florida	750	1300	21	190	73	280
Georgia	500	650	-	57	13	171
Hawaii	50	120	45	5	140	-
Illinois	875	1337	4	47	53	4
Iowa	200	325	3	14	63	250
Kansas	260	550	18	20	112	567
Maryland	450	350	2	74	78	111
Michigan	400	151	0	30	(-62)	1500
Missouri	392	650	-	20	65	(infinite)
New Hampshire	80	110	30	11	38	-
New Jersey	430	437	56	53	2	77
New York	850	1200	3	150	41	168
North Carolina	350	1000	10	50	186	1567
South Carolina	280	350	8	25	25	150
Tennessee	450	680	36	-	42	-
Texas	1900	2100	40	105	11	192
Virginia	900	2500	40	121	-	203
Washington	362	494	-	120	36	-
Wisconsin	250	450	12	45	80	275

Appendix B: Percentage of DOT PE Work Done by Consultants in 1998

State	% of work by consultants	State	% of work by consultants
Arizona	70	Michigan	46
Arkansas	40–45	Minnesota	16
California	15	Missouri	40
Colorado	50	Nebraska	40
Connecticut	70	New Hampshire	35
Florida	80	New Jersey	85
Georgia	25–30	New York	50
Hawaii	60	North Carolina	35
Illinois	80	South Carolina	40
Iowa	40	Tennessee	54
Kansas	60	Texas	30
Kentucky	73	Virginia	65
Louisiana	50	Washington	15
Maryland	70	Wisconsin	37
Massachusetts	50	Wyoming	10–15

Appendix C: Interview Questionnaire

"TxDOT Project Delivery Business Model"
Interview Guide/Questionnaire

Objective: The main objective of this interview is to collect information about how TxDOT goes about deciding on what PE work is done in-house or contracted to consultants. It aims to gather data regarding the tools/procedures used, factors that are used in the decision process, PE programs/projects/functions most often outsourced, and whether there is any follow-up or feedback on the final product.

Our request: Please email Krishnaprabha K R [krishnakr83@gmail.com] with some dates/times when you can fit us in for a telephone interview (and your preferred phone number). We anticipate taking no more than 30 minutes of your time. Alternatively, you can fill out whatever you can in this file and email it back to krishnakr83@gmail.com with some dates/times when we can call you to follow-up. We would like to complete this data collection by the end of June.

Date of interview:
Name of the Interviewee:
Primary job function:
Experience in consultant management field:
Other information:
Phone and email:

1. ***How do you assess the staff and related requirements for a particular program of work? (e.g., 3 year letting schedule)***
2. ***Can you give more information about the procedure used to estimate the In-house staff availability?*** Do you have a formula or procedure for calculating the manhours/time required for a particular project?
3. ***Please tell me all the steps you go through in making the decision on who does some or most of the PE work in a program? (In-house or consultant) Who makes that decision?*** Do you have some rules for deciding which jobs can be done in-house and which must require consultants?

4. ***What are the factors you consider in the outsourcing decision making process? (e.g., In-house capabilities)***
    - Do you have a checklist of complexity factors or required skills that you use to classify a job as 'doable in-house' or 'requires a consultant'? Would such a list be useful?
5. ***What PE functions/projects/program do you most often outsource, and what are the reasons?***
6. ***How do you estimate your district's consultant needs in response to the request from Consultant Contract Office?***
7. ***Which contract type (indefinite deliverable or definite deliverable) is used commonly and why?***
8. ***How do you revise the work plans after getting the PE budget allocation from CCO?***
9. ***Could you explain the cost tracking system (both direct and indirect) for consultant projects?***
10. ***What all expenses are incurred due to outsourcing, rework, etc, and are they charged to specific projects or to district overhead?***
11. ***What problems (if any) have you experienced with the current decision making process?*** Do you think your current process causes you to overuse or underuse consultants? Do you think it affects in-house capabilities or morale?
12. ***Can you give suggestions to improve the current decision making process?***
13. ***What do you think the minimum In-house capability/resource level to effectively manage your work program for the following cases?***
    - ***If all done In-house***
    - ***If all done by consultant with TxDOT oversight***
    - Would like to know current number of direct and support staff involved in project development
    - Would like to know annual volume of consultant work ($ spent on consultants, and associated letting $) over last 3 years, and projection for next 3 years

- Would like to know annual letting volume for last three years and next three years
- Please suggest an ideal mix of in-house and consultant works to maintain in-house capabilities? (A ratio like 70% in-house and 30% consultants etc)

14. ***What is your opinion about consultants managing consultant projects? (quality of work, conflict of interest etc)***

Follow up

We will document what we have just discussed and email it to you one week from today for verification/comments. Can we set up a time after that for me to call you so we can discuss your comments?

Appendix D: Manhour Estimation at TxDOT PE Function Code Level

Note: "Median" is the median hours observed for that function in the projects studied. "-2nd Std" is the hours below which only 2.5% of the observations fall. "-1st Std" is the hours below which only the lowest 16% of the observations fall. Similarly, "+1st Std" and "+2nd Std" are the hours above which, respectively, only 16% and 2.5% of the observations fall. These numbers are provided to give a sense of the range observed. In general, higher project construction cost corresponds with higher hours required.

DCIS Project type	In-house Function	Required Hours (2006-07 data)				
		Median	-2nd Std	-1st Std	+1st Std	+2nd Std
BR	102	30	14	20	43	63
BR	110	22	12	16	29	40
BR	120	107	83	94	122	138
BR	130	17	9	12	22	30
BR	145	28	20	24	34	40
BR	150	100	44	67	150	226
BR	160	186	112	144	241	311
BR	161	87	52	67	113	146
BR	163	191	112	146	248	324
BR	164	72	48	59	89	109
BR	170	186	104	139	249	334
BR	180	46	37	41	51	56
BR	181	26	22	24	28	31
BR	182	27	22	24	30	33
BR	190	9	6	8	11	13
BWR	110	24	9	15	39	63
BWR	120	87	62	74	103	121
BWR	145	43	24	32	57	77
BWR	160	240	73	132	434	787
BWR	163	331	121	200	548	908
BWR	164	55	25	37	82	123
BWR	170	182	44	90	369	749
BWR	180	55	37	45	67	82
BWR	181	40	30	35	46	53
BWR	182	25	18	21	30	35
CTM	181	23	14	18	31	40
INC	145	93	41	62	140	211
INC	160	1202	480	760	1902	3009
INC	162	347	114	198	606	1059
INC	164	339	136	214	536	847

DCIS Project type	In-house Function	Required Hours (2006-07 data)				
		Median	-2nd Std	-1st Std	+1st Std	+2nd Std
INC	165	151	54	91	253	421
INC	180	224	160	189	265	314
INC	181	49	32	40	60	74
INC	182	68	46	56	82	99
INC	190	42	18	28	63	94
LSE	120	16	9	12	22	29
LSE	160	56	35	44	71	90
LSE	163	69	46	56	85	105
LSE	164	29	17	22	37	48
LSE	180	32	25	28	37	42
LSE	181	13	11	12	14	16
MSC	102	8	3	5	13	21
MSC	110	28	18	23	35	44
MSC	120	33	24	28	39	45
MSC	130	28	16	21	37	49
MSC	145	27	18	22	33	40
MSC	150	37	23	29	47	60
MSC	160	155	113	132	182	213
MSC	161	132	70	96	182	250
MSC	162	129	91	108	153	183
MSC	163	132	98	114	153	177
MSC	164	59	38	47	73	92
MSC	165	110	41	67	180	294
MSC	170	29	14	20	41	58
MSC	180	38	32	35	41	45
MSC	181	24	21	22	26	27
MSC	182	29	23	26	32	37
MSC	190	12	8	10	14	17
OV	110	30	15	21	42	59
OV	120	16	8	11	22	31
OV	145	37	25	30	46	56
OV	150	27	17	21	34	43
OV	160	95	72	83	110	127
OV	162	48	29	38	61	78
OV	163	98	70	83	115	136
OV	164	15	8	11	21	29
OV	180	40	33	36	44	48
OV	181	24	20	22	26	29
OV	182	14	9	11	17	21

DCIS Project type	In-house Function	Required Hours (2006-07 data)				
		Median	-2nd Std	-1st Std	+1st Std	+2nd Std
OV	190	5	4	5	6	7
RER	102	9	5	7	12	16
RER	110	28	18	22	36	45
RER	120	46	35	40	52	60
RER	130	19	10	13	26	36
RER	145	40	26	32	49	60
RER	150	91	51	68	121	162
RER	160	380	262	316	458	552
RER	161	110	68	87	139	176
RER	162	60	33	45	81	110
RER	163	302	216	255	357	422
RER	164	72	39	53	99	135
RER	170	29	10	17	48	79
RER	180	71	60	65	77	83
RER	181	38	33	36	41	44
RER	182	28	22	24	31	35
RER	190	12	8	10	14	18
RES	110	46	23	32	65	92
RES	120	40	28	33	48	57
RES	150	48	25	35	66	92
RES	160	170	108	136	213	267
RES	161	135	71	98	186	255
RES	162	25	10	16	38	58
RES	163	355	219	279	451	574
RES	164	39	16	25	62	97
RES	180	68	58	63	73	79
RES	181	34	27	30	38	43
RES	190	13	5	8	20	32
SC	110	23	11	16	35	52
SC	120	11	4	7	18	29
SC	150	35	18	25	50	70
SC	160	48	32	39	58	71
SC	162	47	19	30	74	117
SC	163	95	67	80	114	136
SC	180	45	35	40	50	56
SC	181	11	8	9	14	17
SC	190	25	10	16	39	60
SFT	102	32	16	23	46	65
SFT	110	17	12	14	20	24

DCIS Project type	In-house Function	Required Hours (2006-07 data)				
		Median	-2nd Std	-1st Std	+1st Std	+2nd Std
SFT	120	55	47	51	60	65
SFT	130	17	11	14	21	26
SFT	145	25	17	20	30	36
SFT	150	78	54	65	93	112
SFT	160	200	147	171	233	271
SFT	161	78	50	62	97	122
SFT	162	58	40	48	69	83
SFT	163	200	157	177	225	254
SFT	164	58	42	49	67	79
SFT	170	32	16	22	45	63
SFT	180	47	41	44	50	54
SFT	181	29	26	27	30	32
SFT	182	20	16	18	22	24
SFT	190	8	6	6	9	10
TS	120	9	4	6	14	21
TS	162	123	68	92	165	221
TS	163	34	16	23	49	71
TS	164	41	18	27	61	90
TS	180	26	18	22	31	37
TS	181	17	13	15	19	22
TS	182	14	9	12	18	23
UPG	180	115	51	76	173	260
UPG	181	59	45	52	67	77
WF	145	195	66	114	334	573
WF	180	200	87	132	301	455
WF	181	44	20	29	65	97
WF	182	102	52	73	144	203
WNF	102	10	5	7	14	20
WNF	110	129	60	88	188	275
WNF	120	100	43	66	153	233
WNF	145	89	50	67	119	160
WNF	146	37	23	29	48	61
WNF	160	575	229	363	912	1445
WNF	161	562	268	388	815	1180
WNF	162	170	86	121	239	336
WNF	163	468	209	313	699	1045
WNF	164	240	145	186	309	398
WNF	170	107	25	52	223	462
WNF	180	145	112	127	164	187

DCIS Project type	In-house Function	Required Hours (2006-07 data)				
		Median	-2nd Std	-1st Std	+1st Std	+2nd Std
WNF	181	52	41	46	60	68
WNF	182	37	27	32	43	51
WNF	190	29	15	21	40	55

Source: Persad & Singh, 2009 (statistical results, not included in the research report)