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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 2012. Three tasks were completed and are documented.		
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RTI Special Studies for TxDOT Administration in FY 2012

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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 FYs 2011–2012 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 technical memorandums for the task, to provide TxDOT with implementation information in a timely manner. This report combines the various technical memoranda completed in FY 2012 for easy reference, and is a follow-up to Report 0-6581-1, -2, and -3, which documented the work completed in FYs 2009, 2010, and 2011, respectively.

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

The following three tasks were undertaken in the period September 2011 to August 2012:

Task 12 (FY 12): Assessment of TxDOT FTEs for Project Development and Construction, and PS&E Backlog Analysis—Continuation

The objective of this task was to examine full-time-equivalent (FTE) staffing needs for TxDOT project development and construction, and analyze needs for "backlogging" PS&E, i.e., preparing construction plans in advance and keeping them "on the shelf" for possible construction funding in the future. As TxDOT developed its long-term work programs ("PDP12" and "PDP13"), the research team would provide support to the TxDOT work teams.

Task 13 (FY 12): Assessment of durations and staffing needs for environmental approvals

The objective of this task was to provide an independent assessment of work conducted by a TxDOT team on the durations and staffing needs for various levels of environmental document types required for TxDOT projects. Where necessary, the researchers will gather additional data and conduct additional analyses to refine the existing estimates, and make recommendations for incorporating the results into the TxDOT PDP-2012 effort and assist with the manpower needs assessment for the environmental phase of the project development process.

Task 14 (FY12): Development of a spreadsheet based model of S101 staffing needs for use by the TxDOT Modernization Team

The objective of this task was to develop a spreadsheet-based FTE staffing tool for computing TxDOT Strategy101 staffing needs. The objective of the tool was to allow TxDOT staff to utilize the results of the various staffing models within a spreadsheet environment and utilize these with the known and proposed funding scenarios that TxDOT staff may be asked to evaluate for impacts on TxDOT staffing and consultant needs.

1.3 Organization of This Report

This chapter presented the background and justification for this research effort, and the research tasks. At different stages of each task the research team submitted technical memoranda and presentations to TxDOT. This report combines the technical memoranda and presentation materials for easy reference.

Chapters 2–4 present the results of Tasks 12–14 respectively. Conclusions and recommendations are contained within each chapter.

Chapter 2. TxDOT FTEs for PE and CE, and PS&E Backlogging

2.1 Introduction

Task 12 (FY 12): Assessment of TxDOT FTEs for Project Development and Construction, and PS&E Backlog Analysis—Continuation

The objective of this task was to examine full-time-equivalent (FTE) staffing needs for TxDOT project development and construction, and analyze needs for backlogging PS&E, i.e., preparing construction plans in advance and keeping them "on the shelf" for possible construction funding in the future. As TxDOT developed its long-term work programs ("PDP12" and "PDP13), the research team would provide support to the TxDOT work teams.

In FY 11, the research team examined full-time-equivalent (FTE) staffing needs for TxDOT project development and construction, and began to analyze needs for backlogging PS&E. In FY 12 this work was continued to complete analyses requested by the TxDOT panel as a result of additional complexities identified during development of the department's PDP-2012 (four-year work plan), and to address changes in funding enacted by the 82nd Texas Legislature.

Backlogging was a major focus of the FY 12 work plan. In recent years, the Texas Legislature instituted a series of 'one-time' infusions using Proposition 12 and Proposition 14 bonds to augment traditional transportation revenues. The 2009 Federal American Recovery and Reconstruction (ARRA) stimulus funds represented a further one-time infusion that provided a short-term cash flow stimulus for constructing 'shovel-ready' projects. The 82nd Texas Legislative session approved the second tranche of Proposition 12 bonds (P12V2) that raises cash flow, requiring TxDOT to meet a combined letting obligation of approximately $8.4 Billion in FY12 and FY13. However, prior to this development TxDOT had been planning to let far less than that figure in construction projects based on forecasted revenues from traditional sources—as mandated— and was on a sustained path to reducing departmental workforce size to meet the lower design and construction volumes.

The infusions from P12V2 and the mandated letting targets require TxDOT to quickly identify projects that meet the legislative goals and appropriations requirements included in the legislation. Most transportation projects (beyond simple sealcoats and overlays) require years of planning, development, and coordination. Therefore, TxDOT has reached into an already diminished reserve of 'backlog' projects to identify those that meet P12V2 requirements for letting in FY12 and FY13.

The 'one-time' infusions make it harder for the Department to predict actual 'cash-flow' volumes and therefore schedule the appropriate volume of work to be developed and held until needed, and let within each fiscal year. In addition, this uncertainty impacts the staffing needs for developing, letting and managing design and construction projects and the staff needed to hire, manage and oversee the consultants used to augment the TxDOT staffing needs. In FY 11, under this research task CTR developed models for predicting CE and PE staffing needs, by collecting and analyzing historical productivity data. CTR developed and refined an initial set of models that can be used to predict staffing needs for a future portfolio of design and construction projects. In FY 12, CTR continued refining these models to account for a number of complexities identified while the department developed its four-year work plan.

2.2 Task 12A. Backlog Analysis

Backlogging formed a major focus of the FY12 Task 12 work plan, since a firmer definition of how the term is defined and implemented is emerging within the department. This allowed the CTR team to survey other states to see if any are addressing similar needs, identify, and describe the processes they are using, collect data on the type and characteristics of the projects they select, and use the information to compare the key features with those projects being developed in TxDOT.

The subtasks in Task 12A were the following:

1. Interview departmental staff who are working on backlogging, and derive a basic definition and set of characteristics which can be shared with others outside the state.
2. Develop a set of states whose DOTs manage a highways network that could be regarded as similar to that of Texas and also contacts states that are known for their innovation, particularly in the funding, planning and policy arenas. The researchers contacted AASHTO through TxDOT's Deputy Executive Director and sought their help and resources to derive contacts at the state level where backlogging may be implemented.
3. Develop a questionnaire, present to the TxDOT panel, and test first within TxDOT and then on at a least one other state DOT. This constituted the critical step of pilot testing the approach and making corrections to enhance its effectiveness.
4. Survey the states sampled from (2) above and draft an interview memo for each respondent, together with any data that can be provided to describe the size, cost and characteristics of the projects, as well as any constraints that affect backlogging, so that comparisons can be made with those selected by TxDOT. Upon PD approval, the finalized survey document was sent to those states selected as most likely to impact Texas backlogging, with follow-ups as necessary.
5. The comparisons will be developed and then reviewed in detail by the CTR team to insure that all the key categorizations, construction scheduling, planning, and economic factors are addressed. The results will then be presented to the TxDOT panel for review.
6. Changes recommended by the TxDOT panel will be addressed and a final report drafted. Regular updates were provided to the panel, at least once per month.

These, once edited will form the body of the report, and an executive summary will be added for policy makers to access as needed.

2.2.1 Use of ARRA Funds by State DOTs

The following is Technical Memorandum 3 submitted for this task.

Technical Memorandum 0-6581-T12-TM3
Backlog Analysis: Use of ARRA Funds by State DOTs
Primary Author: Lisa Loftus-Otway
Date: October 2011

This research task is examining TxDOT PE and CE staffing needs, and strategies for developing backlog projects. One area of interest is how other state DOTs deal with unexpected influxes of funds. The American Recovery and Reinvestment Act (ARRA) of 2009 appropriated $27.5 billion for highway projects. State DOTs were tasked to obligate these funds by March 2010 on "shovel-ready" projects, after which the USDOT could re-distribute unobligated funds by September 2010.

This technical memorandum outlines some of the findings from two Government Accountability Office (GAO) audits in 2009 and 2011.[1] These findings show which states were able to obligate funds quickly and the types of projects they undertook, giving insight into potential states to be interviewed regarding backlogging.

Summary of Findings

Figure 2.1 shows the GAO findings on state DOT obligations by project type in late 2009 and in mid-2011.

The studies noted that pavement work formed the bulk of projects (70%), because they were quick to design and let. New road construction amounted to just 6-7% of the total, with bridge projects another 12-13%. In the 2009 GAO report, many states said that they "*did not have programs in place for 'shovel-ready' projects, and did not have procedures and software to identify these short-term type projects easily*." The 2011 GAO report noted that *"recovery funds helped reduce* ***backlogs*** *of shovel-ready projects."* California, for example, stated that *"it funded its entire list of shovel-ready projects and began work on new construction projects."*

Both reports found that the mix of projects would have been different had they been given more time to obligate the funds. California, Florida, Iowa, Ohio, North Carolina, Pennsylvania, Virginia, and Washington appear to have been the most innovative in using ARRA funds, and the research team proposes to interview them to understand their approach to developing backlog projects.

[1] United States Government Accountability Office (GAO). December 10, 2009. *Recovery Act: States' use of Highway and Transit Funds and Efforts to Meet the Act's Requirements.* GAO-10-312T. Accessed on September 26, 2011 from http://www.gao.gov/new.items/d10312t.pdf; and GAO. June 29, 2011. *Recovery Act: Funding Used for Transportation Infrastructure Projects, but Some Requirements Proved Challenging.* GAO-11-600. Accessed on September 26, 2011 from http://www.gao.gov/new.items/d11600.pdf

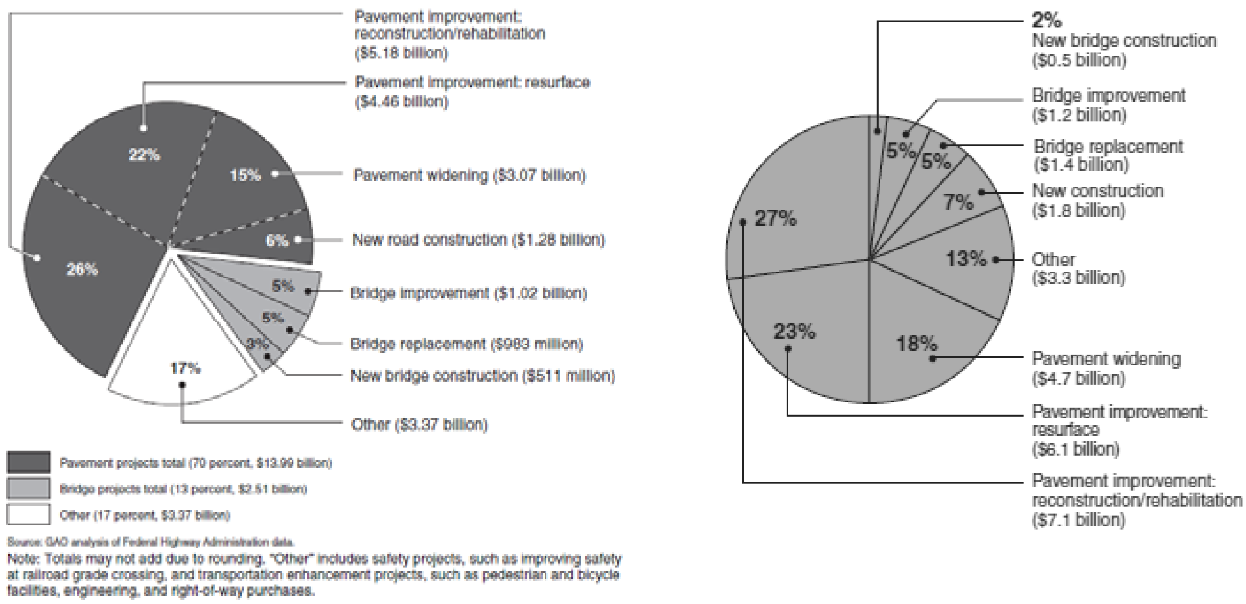

Figure 2.1: ARRA Obligations by Project Type as of Oct 31, 2009 and Jun 3, 2011

<u>GAO Report GAO-10-312T—December 10, 2009</u>

In the first report, GAO reviewed 16 states and the District of Columbia.[2] These states were chosen because they contain about 65% of the U.S. population, and were estimated to receive collectively about two thirds of the funds available from the Act based on outlay projections, unemployment ranges, mixtures of poverty levels, geographic coverage, and rural/urban representation. The audits were conducted between September and December 2009. Table 2.1 shows the level of funds apportioned in the 16 states reviewed, obligation amounts, and most importantly the percentages that had been apportioned by these DOTs as at November 2009.

GAO found that states were continuing to dedicate most of the funds for pavement projects, although there was some variation on use depending on state transportation goals. State officials told GAO that they selected these projects because they did not require environmental clearance, did not need extensive design, and could be quickly obligated and bid. *Notably, construction of new roads and bridges respectively accounted for just 6% and 3% of funds obligated.*

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[2] Arizona, California, Colorado, Florida, Georgia, Illinois, Iowa, Massachusetts, Michigan, Mississippi, New Jersey, New York, North Carolina, Ohio, Pennsylvania and Texas.

Table 2.1: ARRA Apportionments and Obligated Amounts at November 2009

State	Apportionment $ (millions)	Obligated Amount	% of Apportionment Obligated	Key
AZ	522	299	57	
CA	2570	2085	81	
CO	404	346	86	
DC	124	106	86	
FL	1347	1123	83	
GA	932	710	76	50-60%
IL	936	784	84	
IO	358	342	96	60-70%
MA	438	252	58	70-80%
MI	847	716	84	80-90%
MS	355	306	86	
NJ	652	492	75	90%+
NY	1121	833	74	
NC	736	659	90	
OH	936	488	52	
PA	1026	925	90	
TX	2250	1396	62	
Source: GAO-10-312T page 5-6				

Notable findings of the 2009 GAO report included

- Illinois and Iowa obligated a significant portion of ARRA funds for resurfacing—63 and 59% respectively. This compared to 10% and 12% of funds in Pennsylvania and Florida. Iowa noted, however, that this was a strategy they took to advance a large number of projects in this one area, and free up funds for larger, more complex projects in the near future.
- Mississippi used over half of ARRA funds for pavement improvement; of this 14% went to pavement widening.
- Florida used 36% of funds for pavement widening (compared to 15% nationally) and 23% for construction of new roads and bridges (compared to 9% nationally).
- Ohio obligated 32% of funds for new road and bridge construction.
- Pennsylvania targeted their funds to reduce the number of structurally deficient bridges in the state. At October 2009, 31% of funds were obligated to bridge improvement and replacement (compared to 10% nationally).
- Massachusetts had used the bulk of its funds at this juncture for pavement improvement 30% for resurfacing and 43% for reconstructing/rehab of roads. Massachusetts noted that for future project selection they were going to select projects that promoted longer term goals of the state—e.g., construction of a new

interchange and access roads to a proposed executive park. GAO noted that FHWA officials expressed concern to GAO that this strategy may be too ambitious and could run the risk of not meeting act requirements by the final obligation date in March 2010.

- Analysis found that for 10 states, contracts were awarded at less than original cost estimates. California, Georgia, and Texas awarded more than 90% of their contracts for less than estimates.
- Some states noted that while they were committed to trying to meet their maintenance of effort requirements, they were concerned that they may not be able to maintain their levels of transportation spending if gas tax and other revenues declined, or if agency cuts were implemented due to lower 2009/10 state revenue collections.
    - Iowa, North Carolina, and Pennsylvania—all high obligation states at an early juncture—noted this was a concern for them.

<u>GAO Report GAO-11-600—June 29, 2011</u>

For the second report GAO visited six states and DC (California, Indiana, Massachusetts, Texas, Virginia and Washington) which represented about 25% or \$6.9 billion of the \$27.5 billion available from ARRA. They were also geographically dispersed, with a mix of more and less populated states, and were drawn as a mixture of the previous 16 states that had been monitored. The reported noted that at its time of writing—May 2011—almost 95% of the \$45 billion of ARRA funds had been obligated in over 15,000 projects across the U.S. Pavement improvement projects had continued to be the primary use of AARA funds. As discussed in the 2009 report, states did experience problems with the maintenance of effort requirements. This required that states maintain their planned level of spending to be eligible for the August 2010 redistribution. GAO found that 29 states met this requirement, but 21 states did not.

Notable findings included the following:

- Rates of expenditures still varied among programs and states
- Obligation and subsequent expenditure for highway funds sub-allocated for metropolitan, regional, and local use have lagged behind rates for state projects in some states. According to FHWA this trend had continued for 24 states, including Texas and Virginia—states visited by GAO.
- 68% of funds were used for pavement improvement projects.
- The Act, according to state DOT officials, led to better coordination and streamlined processes. For example Massachusetts DOT noted that they streamlined their 26 step bid process down from 120 days to 44 days.
- DOTs noted that *"AARA funds helped reduce 'backlogs' of shovel ready projects."* California for example, *funded its entire list of shovel ready projects* and began work on new construction projects.

- Other states noted that they could complete projects that were planned but lacked funding. Virginia began construction of an interchange that had been planned since the 1980s. Massachusetts started construction of a bike and pedestrian project that was promised as part of the Big-Dig Project. Washington accelerated work on congestion relief on I-405 and extended a HOV lane on I-5.
- Maintenance of effort proved to be an issue for many states. GAO also noted *that many states did not have an existing means to identify planned transportation expenditures for a specific period*, and their financial and accounting systems did not capture this data.
    - GAO commented that some DOT officials noted a more narrowly focused requirement applying only to programs administered by State DOTs, or programs that typically receive state funding could help address the maintenance of effort challenges.
- Obligations deadlines heavily influenced the types of projects selected for funding.
    - State and local officials noted that to meet Act obligations they prioritized projects that had significantly progressed through the development and design process and could quickly move to construction, and did not require extensive environmental review/processes.
    - This prohibited other potentially higher priority projects from being selected.
- Several states said that their mix of projects would have been different if obligation timelines were longer
    - California noted they would have pursued more large-scale projects.
    - Washington and Virginia said that the Act's obligation timeframes allowed their states to select projects that addressed state priorities, such as infrastructure investment that had long-term economic impacts, and addressed safety and preservation needs.

<u>Conclusion</u>

It appears that different states use the term '*backlog'* differently. The second GAO report noted that *"transportation officials told us that recovery funds helped reduce* ***backlogs*** *of shovel-ready projects."* Whether this term 'backlog' refers to a specific program with a blended mix of projects, or is a term used within the context of its plain meaning to cover projects awaiting funding is not defined. Given that both reports found that many states stipulated that their mix of projects would have been different had there been longer obligation times it is not clear that the term backlog as used in the GAO report matches up to how TxDOT is using this term.

These GAO reports show that many states did not have programs in place for 'shovel-ready' projects. In both sets of drawdowns pavement maintenance and rehabilitation formed the bulk of projects. These types of projects can be quickly assembled for construction. On the other hand, new road construction amounted to only 6% and 7% respectively, mainly because they require extensive environmental review/processes. Even bridge improvement, replacement, and new construction, which require moderate environmental work, were just 13% and 12% respectively.

It would be interesting to see follow-up reporting on how many states were able to shift projects forward post ARRA, as was suggested by some states, because they were able to catch up with what they termed *backlog projects.* Many states noted that their mix of projects would have been different had there been longer obligation times. Clearly, ARRA proved that states need to have a set of backlog projects, for unexpected cash influxes.

Recommended Next Steps

- Interview TxDOT management and settle on a definition for backlog, as there may be confusion with this term when we talk to other states.
- Request approval to interview the following states based on the GAO reports: California, Florida, Iowa, Ohio, North Carolina, Pennsylvania, Virginia, and Washington.

2.2.2 Backlogging Environmental Approvals

Introduction

As the previous technical memorandum noted, one of the major impediments to having shovel-ready projects under ARRA funding was lack of environmental compliance completion for many potential projects. The GAO found that many projects funded under ARRA were selected because they had already progressed significantly through the project development and design process (some 70%). State DOTs who were interviewed by GAO noted that some of their large or new infrastructure projects could not be funded because they required additional reviews, including environmental clearances, which in the short-time frame for ARRA disbursements, could not be achieved.

Many DOTs will not undertake an environmental review until the project has sufficient and predictable financing. The question then arises: how to develop a strategy to have backlog projects that may not fall within the constrained portion of the TIP, but could be sufficiently progressed through the environment, development, and design process to take advantage of new or ad-hoc funding as it becomes available?

In this research task, a review was undertaken to see if there were any entities who, through statutes, policies, or programs, are conducting NEPA/environmental analysis earlier in the transportation planning process. At the federal level the Linking Planning and Environment Initiative was reviewed to see if there was any guidance that could assist in pre-positioning projects. Such guidance may not be in the financially constrained portion of the long range plans, and TIPs, but assessed in the non-constrained portion of the plan.

In addition, two MPO documents were reviewed to ascertain the level of detail in environmental review and whether this could be utilized in a formal project specific NEPA evaluation to assist in reducing project development time as part of a formalized backlog policy and program.

Linking Planning with NEPA

Linking the transportation planning process and the National Environmental Policy Act of 1969 (NEPA) process has been a topic of interest for federal agencies, state DOTs, and MPO's, among others, for over ten years. A limited number of similar individual state programs have been in effect since the late 1990s. Federal laws and guidelines supporting integrating the two processes have been present since mid-2000, with major guidance issued in 2007, and legal guidance issued by the Chief Counsels for FHWA and FTA on linking these processes in 2005. The driving force behind these programs is a desire to streamline the NEPA process itself and to reduce the time it takes to produce the environmental documents as well as the consultation time between various federal, state, and local agencies.

In the past ten years the focus of policy and programs has begun to assess how to draft and develop the long and short range planning documents with a view to integrating segments/components into the environmental documents. However, this review on linking planning and NEPA found that initiatives to link these processes are still fairly sporadic, not yet fully integrated, and have mostly focused on major projects and corridor planning.

However, two states are conducting quite rigorous environmental impact type assessments on their long-range plans. California, already notable for its strong state environmental act, requires Environmental Impact type assessments on all plans and programs developed by any state or local entity. So under California's State Environmental Policy Act, MPO's are required to conduct an Environmental Impact Review on the long range transportation plans, and on projects that are then transferred into the TIP. Washington State also requires a similar type of exercise, although the reviews are called Environmental Impact Statements.

California Environmental Quality Act

California, through its Environmental Quality Act, has legislated for environmental review of long-range planning documents through the California Environmental Quality Act (CEQA) (California Public Resources Code (CPRC) Sections 21000-21178, and Title 14 California Code of Regulations (CCR) Section 753 and Chapter 3, Sections 15000-15387). CEQA requires a Program Environmental Impact Report (PEIR) for any *information document* that discloses the impacts of discretionary government actions on the environment. The Act requires lead agencies to prepare an Environmental Impact Report (EIR) including programs and plans that may cause significant environmental effects.

MPOs/COGs and Caltrans in California are required to prepare a PEIR for their respective regional/state transportation plans, including their Sustainable Communities Strategies. Cities and Counties are also required to conduct a PEIR analysis of the long-range comprehensive plan. For example, the City of San Diego certified its general plan update final PEIR in March 2008 (San Diego, 2008). Under PEIR, agencies evaluate regional scale environmental impacts and indirect effects, including growth-inducing impacts and cumulative impacts. They are also required to identify any potentially *significant* adverse environmental impacts and include any mitigation measures that will minimize these identified impacts.

Local agencies can also integrate the requirements with planning and environmental review procedures that are otherwise required by law or local practice, so that all of these procedures can feasibly run concurrently as opposed to consecutively (CPRC §21003 (a)). Information developed in the EIRs can be incorporated into a database to use subsequent or supplemental environmental determinations (CPRC §21003 (e)).

The PEIR can be prepared on a series of actions that can be characterized as one large project and are related either (1) geographically, (2) as logical parts of the chain of contemplated actions, (3) in connection with issuance of rules, regulations, plans or other general criteria to govern the conduct of a continuing program, or (4) as individual activities carried out under the same authorizing statutory or regulatory authority and having generally similar environmental effects which can be mitigated in similar ways (CCR Guidelines §15168). PEIR can serve as a first-tier document for later CEQA review of individual projects/plans that may be included in the program (CCR §15063 (b) (B) and §15179).

Similar to the Council on Environmental Quality (CEQ) guidelines for Categorical Exclusion (CE) type projects, the CEQA also exempts some projects from the requirements of conducting an EIR. Transportation projects that are exempted include the following:

- A project for the institution or increase of passenger or commuter services on rail or highway rights-of-way already in use, including modernization of existing stations and parking facilities.
- A project for the institution or increase of passenger or commuter service on high-occupancy vehicle lanes already in use, including the modernization of existing stations and parking facilities.
- Facility extensions not to exceed four miles in length which are required for the transfer of passengers from or to exclusive public mass transit guideway or busway public transit services.
- A project for the development of a regional transportation improvement program, the state transportation improvement program, or a congestion management program prepared pursuant to Section 65089 of the Government Code (CPRC §21080 (b) (10 through 13)).

Washington State Environmental Policy Act

Washington State also requires agencies under the State Environmental Policy Act to develop plan-level environmental impact statements (WAC 197-11-442). Under the Revised Codes of Washington §43.21C.030 all branches of the state, including state agencies, municipal and public corporations, and counties shall

a) Utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on the environment;

b) Identify and develop methods and procedures, in consultation with the department of ecology and the ecological commission, which will insure that presently unquantified environmental amenities and values will be given appropriate consideration in decision making along with economic and technical considerations;

c) Include in every recommendation or report on proposals for legislation and other major actions significantly affecting the quality of the environment, a detailed statement by the responsible official on:

   (i) the environmental impact of the proposed action;

   (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented;

   (iii) alternatives to the proposed action;

   (iv) the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity; and

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented;

d) Prior to making any detailed statement, the responsible official shall consult with and obtain the comments of any public agency which has jurisdiction by law or special expertise with respect to any environmental impact involved. Copies of such statement and the comments and views of the appropriate federal, province, state, and local agencies, which are authorized to develop and enforce environmental standards, shall be made available to the governor, the department of ecology, the ecological commission, and the public, and shall accompany the proposal through the existing agency review processes;

e) Study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources;

f) Recognize the worldwide and long-range character of environmental problems and, where consistent with state policy, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of the world environment;

g) Make available to the federal government, other states, provinces of Canada, municipalities, institutions, and individuals, advice and information useful in restoring, maintaining, and enhancing the quality of the environment;

h) Initiate and utilize ecological information in the planning and development of natural resource-oriented projects.[3]

<u>San Diego Council of Governments</u>

The San Diego Council of Government (SANDAG) completed its Environmental Impact Report (EIR) October 2011. It comprises 1400 pages in the main body of the report and 1400 pages in the technical appendices that accompany the report. The EIR took over two years to complete. The EIR is an evaluation of the environmental effects associated with the adoption and implementation of the 2050 Regional Transportation Plan including its Sustainable Communities Strategy.[4] The EIR was prepared as a Program EIR under CEQA Guidelines Section 15168(a). It reflects the broad, regional nature of the long range plan and its alternatives.

According to the EIR, subsequent activities consistent with the 2050 long range plan *"will be examined in light of this EIR to determine whether additional environmental documentation, such as a negative declaration, supplemental or subsequent EIR, or addendum, must be prepared."* If any subsequent activities are within the scope of the EIR, if SANDAG finds no new effects would occur or no new mitigation measures would be required pursuant to CEQA Guidelines Section 15162, subsequent projects would be considered to be within the scope of this EIR and no further environmental documentation would be required.

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[3] Accessed at: http://apps.leg.wa.gov/RCW/default.aspx?cite=43.21C.030

[4] The Program EIR is prepared in accordance with the California Environmental Quality Act of 1970 (CEQA) (Public Resources Code Section 21000 et seq.), and the Guidelines for Implementation of CEQA (CEQA Guidelines) (14 California Code of Regulations Sections 15000 et seq.)

According to SANDAG, *"an advantage of a Program EIR is that it allows the lead agency to consider broad policy alternatives and "program wide mitigation measures" at an early time when the agency has greater flexibility to deal with basic problems or cumulative impacts."*

The EIR is structured into multiple chapters. The report's initial chapters review the purpose of the EIR and the scoping process that was utilized to develop the preferred alternative along with the public review and participation process. A chapter sets out the environmental setting and characteristics of the region, and then a subsequent extremely large chapter turns to the environmental impact analysis.

The elements reviewed include the following:

- aesthetics and visual resources
- agricultural and forest resources
- air quality
- biological resources
- cultural resources and paleontology
- environmental justice
- geology, soils and minerals
- greenhouse gas emissions
- hazards and hazardous materials
- hydrology and water quality
- land use
- noise
- population and housing
- public services utilities and energy
- recreation
- transportation and traffic
- water supply.

The analysis reviews existing conditions, any regulatory setting elements, significance criteria, impact analysis, mitigation measures proposed and any significant effects remaining after mitigation detailed into 3 out-year timeframes 2020, 2035 and 2050. Specific transportation projects that are scheduled in these various timeframe slots are addressed. Separate sections also detail specific mitigation activities that will be developed and implemented as the plan's specific transportation projects move forward through clearance to design and construction.

The report wraps up with a review of cumulative impacts of the proposed plan. It notes that several major infrastructure projects within authority of other agencies are also planned to occur within the timeframe of the projects from the long range plan, and that these may also play a role in cumulative impacts of projects being implemented. The report looks at some of these proposed projects (high speed rail, coastal trail. border crossings and ports of entry, ports and maritime, petroleum pipelines, airports, and freight rail). Cumulative impacts are reviewed by the multiple issue areas listed previously. Mitigation measures are also discussed in terms of the multiple projects that may induce a cumulative impact. Finally, the report sets out the alternative analysis that agencies are required to consider including analysis of impacts associated with the five alternatives that the long range plan considers.

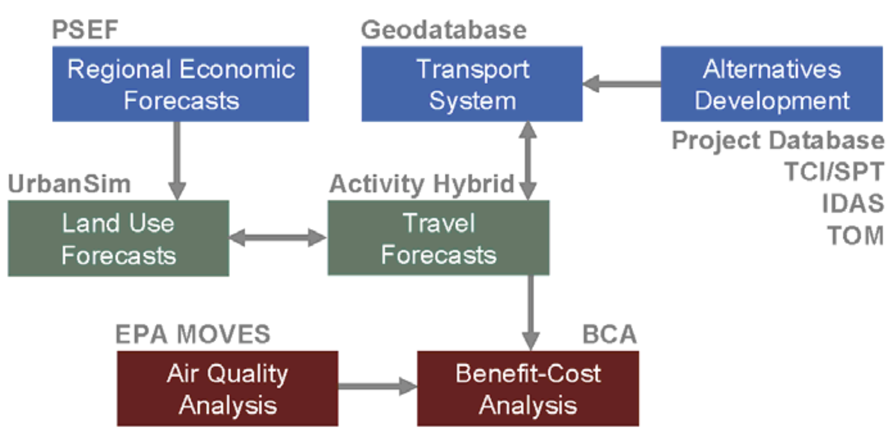
It should also be noted that as part of California's Senate Bill 375, opportunities for streamlining the environmental process when certain criteria are met are used as incentives for implementing projects that are consistent with the long range plans and the sustainable communities strategies that all jurisdictions must develop. If these criteria are met, reviews for specific projects do not require repetition of certain discussion elements. For example, greenhouse gas discussion in terms of VMT in the project-specific environmental review will not need to be repeated and the discussion in the EIR can be utilized.

Puget Sound Regional Council

This Environmental Impact Statement (EIS), completed in 2010 is an extremely large document—comprising some eighteen chapters, and 14 appendices covering around 2600 pages. It took three years to complete. The review covers a large subject matter area because of the COG oversight ambit. For example, it includes sections on public services and utilities, energy, parks and recreation, human health and noise.

The EIS process comprised a scoping process to narrow the plan through input and allow the EIS to focus on the most compelling issues that faced the region. The scoping process had a formalized public input process, so many of the projects that were included within the TIP had already received an element of scrutiny from the public, and state, federal and local agencies, and had become projects that were placed in the preferred constrained (and non-constrained) alternative.

A series of seven models, were utilized to run the various alternatives and the baseline set of data. Figure 2.2 shows Puget Sound's integrated modeling system.



Source: Puget Sound Regional Council
http://psrc.org/transportation/t2040/t2040-pubs/transportation-2040-final-environmental-impact-statement/

Figure 2.2: Puget Sound Integrated Modeling Process

The EIS then reviewed the plans' various alternatives, including the baseline, preferred alternative, and seven other alternatives for impacts to land use, air quality and climate change, noise, visual and aesthetic resources, water quality and hydrology, ecosystems and endangered species act issues, energy, earth, environmental health, historical and cultural resources, environmental justice, and human health in a series of separate chapters and in the appendices.

The agency even completed an environmental justice analysis (not required under Washington's statutes) and hired an outside consultant to conduct public outreach on the various alternatives being reviewed. While the review was not project level specific to the level of compliance required under a full NEPA analysis, conducting such a process with a public outreach component of the magnitude undertaken in Washington should help in identifying projects that could be pushed quickly up the processing and programming chain that may be Categorical Exclusion type projects, or projects that have been shown to have some environmental effects that could be mitigated under an environmental assessment process and not a full NEPA environmental impact assessment.

Since the EIS was released, some non-motorized investments within a one- or three-mile buffer area have been moved into the financially constrained preferred alternative, from the un-programmed portion of the preferred alternative. PSRC notes that this does not change the environmental analysis because the FEIS was conducted on both the constrained and un-programmed part of the preferred alternative.

Conclusion

Linking long-range plans with the NEPA process and securing 'blanket' environmental approvals for segments of those programs could potentially save years off individual project delivery times. Getting MPOs and other local planning agencies that hold the keys to long-range transportation plans involved in environmental approvals appears to be a viable strategy. Leveraging the environmental planning that is already done by those agencies may assist in pre-positioning some projects as environmentally clear backlog projects.

It is recommended that TxDOT work with MPOs to advance the environmental approval process into those agencies' long-range plans. This approach has two benefits:

- Allows longer-duration projects to be 'semi-shelf-ready' for design and construction.
- Allows low impact projects to be identified early and scheduled according to funding.

2.2.3 Survey of State DOTs

Introduction

A general inquiry was made by the research team through TxDOT Deputy Executive Director John Barton to AASHTO to identify state DOTs that have any program to deal with unexpected infusions or surplus funding. Only 7 DOTs responded, and their responses are listed in Table 2.2.

Table 2.2: Initial Responses from State DOTs regarding Backlogging

Agency	Response
Vermont DOT	We do have several prioritization systems that we developed here in VT to address an overabundance of projects with no funding to complete them. They are pretty basic as our goal was to make them transparent to the legislature, general public and planning commissions. Obviously we are a much smaller scale then Texas, but if they are interested, I would be willing to share our experiences.
Michigan DOT	We don't have a backlog issue, per se, but we do have a fairly effective Project Management System that allows us to review development status at the program and individual project level. If you think that helps, I could get you a name of someone here in Michigan that works with that system.
Kansas DOT	I may not understand the question fully. KDOT doesn't have an automated system per se, but we do have a backlog of projects to advance to construction as funding is available. TxDOT can contact Mark Taylor P.E., Chief, Bureau of Program and Project Management for details of our process/procedure.
New Jersey	At the New Jersey Department of Transportation, there is constant evaluation of available funding to determine how much should go towards active construction projects, versus how much should go to project development or project design. As it currently stands, we typically deliver the projects to construction as soon as the design is complete. Due to limited funding, some projects in design are currently on hold. Therefore, our 'shelf' is a list of partially designed projects, but not a batch of fully designed projects
North Carolina	North Carolina has no system for managing backlog projects. We have a few projects that become "shelf projects" as a result of normal business practices and issues.
Indiana DOT	Indiana tries not to have too many shelf ready projects. We only want to work on our set program. We are currently setting our FY15 and FY16 programs. We prioritize our FY projects, estimate the budget, then work towards those means, adjusting as fiscal numbers change. Our fiscal numbers are updated monthly and the program moves with it.
Iowa DOT	We do not have anything like that at the Iowa DOT; however, we would be very interested in their findings.

These state DOTs were contacted to request a follow-up interview, and three agreed: Michigan, Kansas, and North Carolina.

Questionnaire Design

A questionnaire was designed to gather information on State DOT backlogging approaches. The intent was that it would be sent out to the DOTs so they could assemble the relevant facts, and then this would be followed up with a phone interview to elicit details. The design of the questionnaire is illustrated in Figure 2.2.

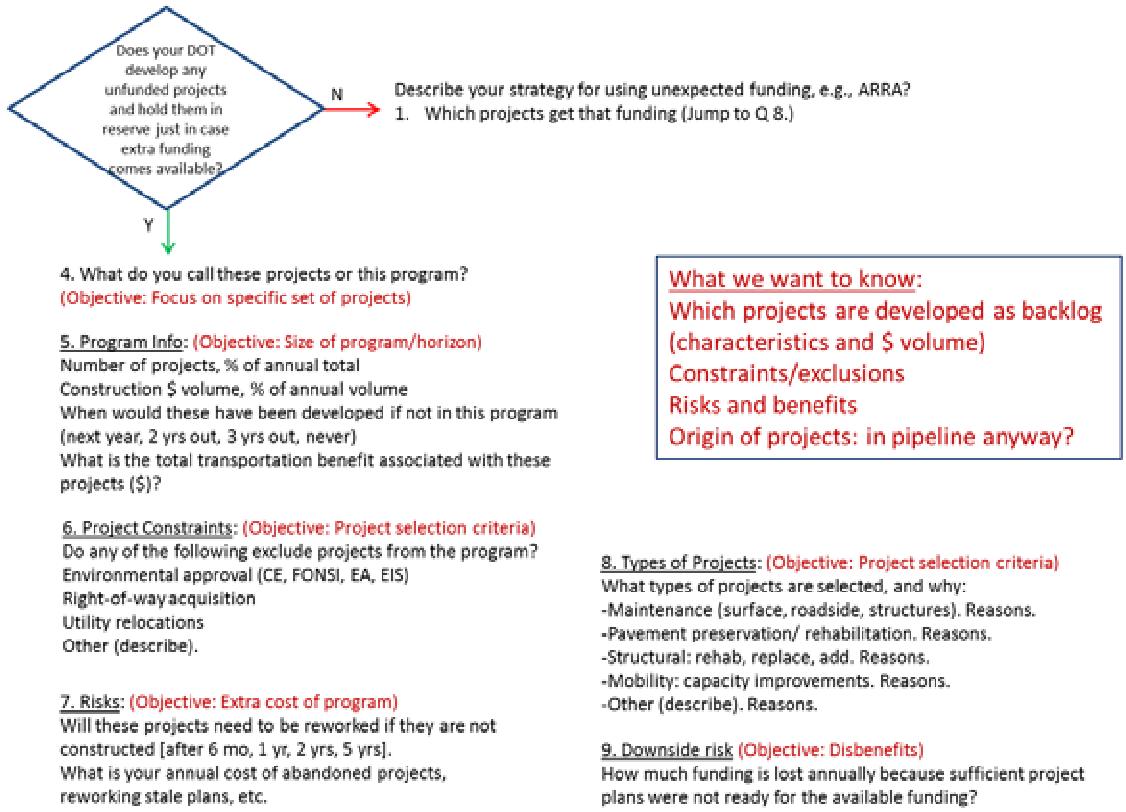


Figure 2.3: Design of Questionnaire for State DOTs on Backlogging Approaches

The screening question was the following: Does your DOT develop any unfunded projects and hold them in reserve just in case extra funding comes available? If so, four pieces of data would be sought:

1. The size of the program, fraction of overall DOT program, and what would have been the fate of those projects otherwise.
2. The types of projects selected and reasons.
3. The constraints that influence the selection of those projects.
4. Risks and benefits associated with developing unfunded projects.

If the DOT did not have a process or program, the questions would focus only on how they deal with unexpected funding, and whether funding is lost because of not having a program in place.

<u>Michigan DOT</u>

Michigan DOT has what they call "shelf jobs." The rationale is that they need to have an even and predictable letting program for the construction industry, so that sharp fluctuations do not impact the demand for construction inputs and adversely affect prices.

In general the DOT tries to complete plans six months ahead of letting date. They aim to let all their larger projects and 75% of their dollars in the first 6 months of the fiscal year (October to March). In this way, even if the more complex projects suffer a delay, they usually can still let it within the FY. They keep only routine projects, e.g., seal coats, for the second half of the FY.

They also develop some shelf jobs from their longer-term program, to 'backfill' for unexpected situations, and to maintain steady workload for in-house staff. There is no formal process for selecting these projects, other than that they be in the rolling 5-year TIP (transportation improvement program). Previously developed shelf jobs scheduled for FY12 letting include the following:

- Mobility: 17 projects totaling $33.5m
- Structural: 6 projects totaling $7.5m
- Pavement preservation: 13 projects totaling $7.8m
- Maintenance: 6 projects totaling $2.1m
- Other: 7 projects totaling $7.6m

Michigan DOT's overall shelf jobs summary for FY12–16 is given in Table 2.3.

Table 2.3: Michigan DOT 'Shelf Jobs' Program for FY12–16

Fiscal Year Program	Shelf Jobs $ (jobs more than six months between PC and let)	Shelf Jobs %
FY12 436 projects $721m	43 projects 51.9m	7.2
FY13 760M	$120.6m	15.8
FY14 $562m	$169.6m	30.1
FY15 $1.07bn	$296.23m	27.5
FY16 $481m	$140.78m	29.3

When unexpected funding is available, Michigan uses its shelf-job projects, and if there are surplus funds they target projects that could be developed in compressed design process (including use of consultants. Regarding the ARRA funding, they said that if they had more time and flexibility, they might have made better strategic decisions on projects they chose, and even on the project delivery process.

North Carolina DOT

NCDOT develops backlog projects, but has no formal process. Those projects used to be called production projects but are now called "backfill" projects. All backfill projects are developed with in-house staff. In general the DOT develops about 5–10% (dollar total) in backfill projects over the funded ones. They have found that this number allows them to use up all their funding each fiscal year. They let their backfill projects continually so as to keep lettings at a steady level.

The DOT tries to manage its cash flow so it would not have to return money to the state's General Revenue Fund, and also uses backfill to manage construction peaks and valleys. NCDOT is very conscientious about using all of its approved funding. Major changes were made after the DOT consistently did not meet its letting targets in the early 2000s. The DOT started using consultants to fill the gaps. They also instituted a better management system to streamline permitting and utility relocations, and/or have contractors work around those.

NCDOT has \$600m in TIP projects (design-bid-build) plus a \$400 design-build turnpike. It lets on average 150–160 projects per year in the regular program, and the backfill program usually comprises 40–50 projects. They are mostly regional and statewide projects that would fall just outside of the TIP programming process. Strategic projects are those that would have been in the pipeline anyway but did not meet current TIP ranking criteria (ADT/Lane width and mobility, and health and safety are the main focus areas). About 60% of the TIP is mobility-focused, with the rest being health and safety projects.

There are two funding authorizations for backfill projects: (i) project scheduled for full funding and letting but just under the criteria set for including in regular TIP; (ii) conduct planning and environmental studies where no ROW has been purchased and there is no letting schedule. Therefore, if they exhaust their lettable projects in a fiscal year, they direct the funds to environmental and planning studies.

Backfill are mostly urban type projects, including

- Multilane sections, curb and gutter, rehab and capacity projects
- Of regional significance
- Not a lot of loops or new construction
- Average range \$60–80m per project

They also take projects that are in years 6–10 of the programming budget. Pavement preservation that is in the \$10–12m range would not fall into the backfill process. The 7-year list of backfill projects is estimated at \$1.6 billion. Occasionally when a backfill project is selected for letting some updating of the plans is needed, usually to the specifications and the mapping. About 1% of the PE budget is spent on reworking those plans, and another 1% of backfill projects end up abandoned.

NCDOT uses a SAP project management software for tracking project development. They use templates with estimated times built in, but many PMs just use the defaults or maximum durations.

ARRA funding was used mostly for resurfacing and infrastructure 'health' type projects that had short construction windows that could work with stimulus guidelines. It was also complex to manage, as 'equity' meant projects had to go to all 100 counties on top of other requirements. They also had to ensure these projects could be finished as they did not have funding to follow on after the ARRA deadline. It appears that the DOT does not obligate funds at letting, but instead manages cash flows to match revenues to construction billings. As a result the ARRA cutoff could have left them hanging.

Kansas DOT

Kansas DOT develops unfunded projects and holds them in reserve, under its 'pooled' projects program. These projects range from expansion to modernization to preservation types. They serve as a 'bank of projects that can be accelerated to fill yearly gaps'. For example, all FY 12 pooled projects are already on the letting schedule. For FY 13 there are two pooled projects totaling $26 m, or 10.1% of the annual letting, while for FY 14 there are a total of $209m in pooled projects—51.8% of that year's letting. The goal is to have a bank of 50% of the annual letting in any given year.

Pooled projects are selected using the DOT's T-Works Program criteria. Figure 2.4 is the website front page for T-Works.

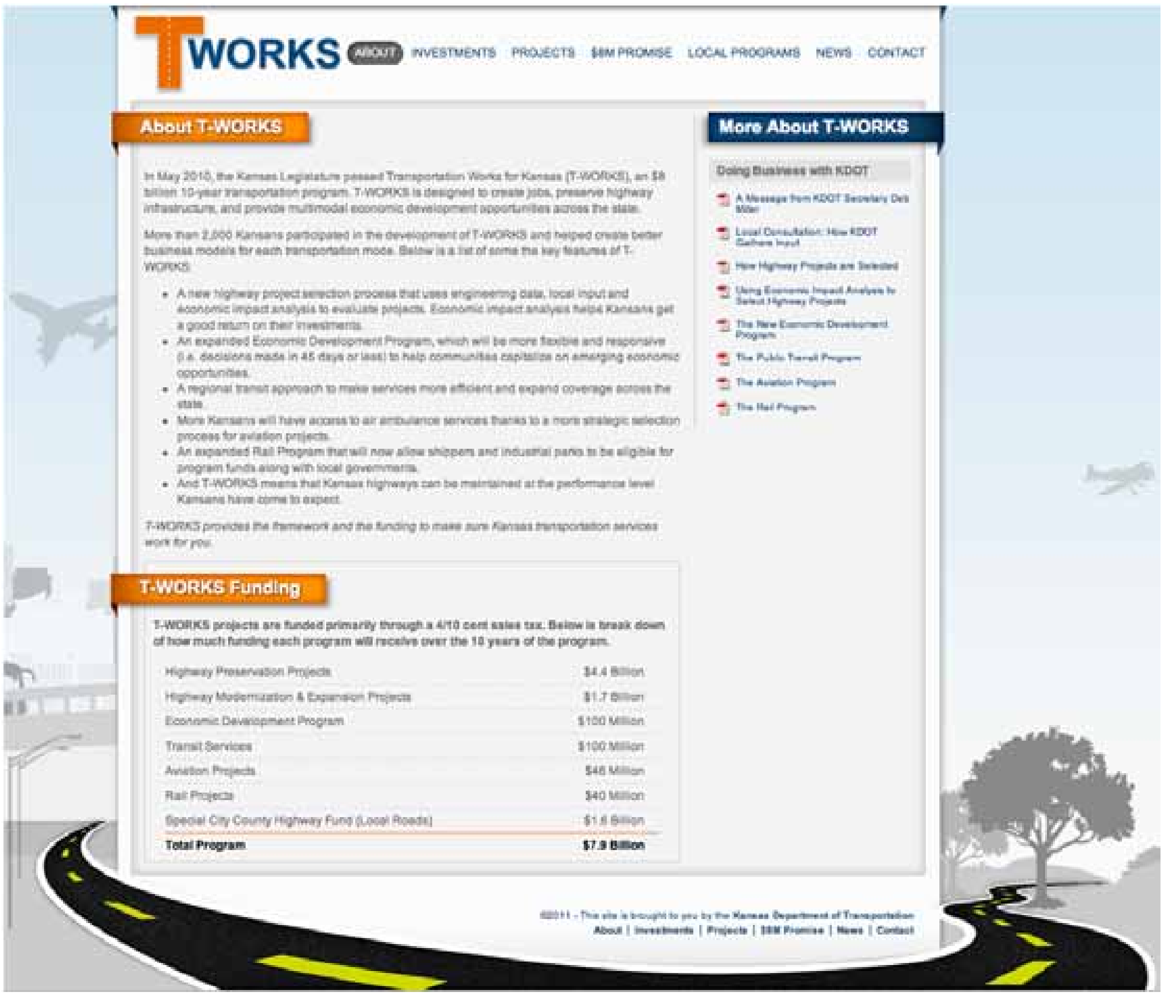


Figure 2.4: Kansas DOT T-Works Website Front Page

Proposed Kansas DOT projects are classified in three groups, with selection criteria and weighting factors as shown in Table 2.4.

Table 2.4: Kansas DOT Project Selection Approach and Weighting Factors

	Engineering	Regional input through local consult meetings	Economic Impact Analysis based on TREDIS (*see economic impact page)*
Preservation projects Taking care of what we have. Pavement and bridge repair and replacement.	100%		
Modernization projects Improving existing roadways. Adding shoulder, flattening hills, improving intersections.	80%	20%	
Expansion projects Adding something new like passing lanes, building additional lanes, and building new interchanges.	50%	25%	25%

Be watching for: Kansans emphasized that transportation investments should support the economic priorities of the state. KDOT now does that for expansion projects through economic impact analysis and by conducting local consult meetings every two years. Be watching for those meetings – that's a great opportunity to talk with KDOT staff and let them know how your community is changing and, consequently, how your transportation needs are also changing. KDOT tried to build some flexibility into the selection and programming process, so that high priority emerging needs can be addressed on a limited basis.

T-Works uses economic impact analysis as factor in project selection. The economic model TREDIS is used to evaluate long term jobs, gross regional product, safety benefits, and income growth. These are weighed against project cost. County-level data is used and rural and urban projects are scored separately.

Table 2.5 illustrates how some projects are evaluated.

Table 2.5: Project Evaluation in Kansas DOT T-Works

PROJECT	PROJECT COST	JOBS ADDED	ECONOMIC VALUE ADDED
Parsons– US-400 Bypass	$27 M	1,400	$56 M
Wichita— K-96 Bypass	$103 M	24,000	$1.6 B
WY County — 110th Interchange	$50 M	5,700	$186 M
Overland Park— Nall Interchange	$48 M	17,500	$4.1 B
Hays — Commerce Parkway Interchange	$3.5 M	2,200	$111 M
TOTAL	**$231 M**	**50,800**	**$6.1 B**

Table: **There are also long-term effects from projects. For example, five case studies on Kansas transportation projects revealed that those projects created more than 50,000 jobs and added $6.1 billion to the state's economy. And it's anticipated that by utilizing economic impact analysis, T-WORKS will generate even greater economic benefits across Kansas.**

For the public input process, the DOT compiles a list with calculated engineering score in terms of pavement condition, safety, congestion, truck traffic, etc. The list is presented to local communities, who can add projects and identify priority projects. Each project is assigned a local consultation score that is calculated based on safety, regional impact, system connectivity, and extenuating circumstances.

Local highway engineers work with partners to gather data on economic impact to feed into the TREDIS model for the economic impact score. DOT planning staff combine the engineering score (50% weight) with the local consultation score (25% weight) and economic impact score (25% weight). These are combined with other factors, e.g., ROW acquisition, system condition, project costs, and design for the final selection process.

T-WORKS projects are funded primarily through a 4/10 cent sales tax with the following 10-year breakdown:

Highway Preservation Projects	$4.4 Billion
Highway Modernization & Expansion Projects	$1.7 Billion
Transit Services	$100 Million
Aviation Projects	$100 Million
Rail Projects	$ 46 Million
Local Roads	$ 40 Million

In general, pooled projects that are sitting on the shelf 5 years or less require minimal rework (primarily changes in standard drawings, etc.). This applies to the preservation and modernization projects that are pooled. The exceptions would be those expansion projects in urban areas where right-of-acquisition has not occurred and development impacting the project footprint has occurred. These projects may require greater rework.

For "Pooled" projects that are subsequently let in later years, environmental approval may need to be reassessed (after a 3 year delay), particularly if something significant has changed—project scope, project footprint, etc. However, normally this reassessment period is minimal and would not greatly impact the project letting.

KDOT is not experiencing lost funding. Cash flow is analyzed and managed extensively throughout the year. There have been an adequate number of "Pooled" projects ready for available funding (resulting from lower than expected bids, delays in planned projects, etc.). More importantly, TWORKS is a 10-year program and is being managed as a program with targeted 10-year expenditures for the various type projects: preservation, modernization, and expansion. Regarding ARRA, KDOT will only have $300,000 of unobligated ARRA funds (out of $378 million provided).

The ARRA funding was distributed as follows:

Highways= $348 million
- State Highways = $268 million
- Kansas City = $22 million
- Wichita = $16 million
- Local governments = $32 million
- Transportation Enhancements = $10 million

Transit = $30 million
- Urban Providers = $16 million
- Rural Providers = $14 million

KDOT was committed to ensuring that a large percentage of ARRA funding went to the two metropolitan areas as well as local governments. The ARRA funding was used to complete 4 major projects that were part of KDOT's previous 10-year Comprehensive Highway Transportation Program, a high profile project with Congressional earmarks, and 140+ city and county projects. Extensive consultation occurred between KDOT's 6 District Engineers, 26 Area Engineers, and local entity stakeholders in identifying and prioritizing ARRA projects.

2.2.4 District Preferences on Backlog Projects

TxDOT districts were surveyed as to what types of projects would be suitable candidates for backlogging. Table 2.6 is a summary of the results.

Table 2.6: TxDOT District Preferences on Backlog Projects

District	What types of projects would you develop as backlog?
Abilene	ABL typically does PM projects as backlog. But then they can sit for 6 months. Then you have to redo the plans because the pavement conditions changed. Best backlogs are BR, rehabs or other construction, because they are independent of what is existing. But one rehab sat for 2 years, now it needs 2 months to refresh because the specs and bid items changed. That's a lot of effort. You need to have the ENV done way ahead, so backlogging really makes an assumption that you have the money lined up. Having projects ready 3–6 months in advance is a better technique for backlogging. Another issue is financial constraints often determine the scope of a project, so if you don't know how much money is there (e.g., local input, etc.), it is hard to develop a set of plans.
Amarillo	The Amarillo district usually develops backlog projects consisting of long range planning, corridor, and connectivity type projects. These types of projects are good backlog candidates due to the large amount of lead time they usually take to develop the project details (public involvement, ROW mapping, and acquisition, development of PS&E, etc.)
Atlanta	Rehab projects in order to meet needs and take advantage of any additional funds that become available, and mobility projects because of the lengthy project development time/process.
Austin	Rehab projects that were up for life cycle repairs that wouldn't fit into the 4-year plan; Safety projects that have never made the safety program but make sense; Added Capacity projects that may not need a lot of ROW or utility adjustments and have regional impact; Larger added capacity projects that may have statewide significance which may make them eligible for special funding sources.
Beaumont	Larger added capacity projects that may have statewide significance which may make them eligible for special funding sources
Brown wood	Rehabilitation projects. Preserve our system and enhance safety.

District	What types of projects would you develop as backlog?
Bryan	Preventive Maintenance (Overlay): PM projects are key to preserving the system. They can be tailored to a specific dollar amount and are relatively easy to dust off and add to a letting if and when funds become available. Rehabilitation: Rehabilitation Projects are key to preserving the system and usually have the extra benefit of bringing the roadway up to current design standards with respect to lane and shoulder widths. They enhance safety by addressing issues associated with pavement width and cross-drainage and parallel drainage structures. Bridge Replacement: Bridge Replacement Projects are key to preserving the system. Given the complexity of some bridge replacement projects and the time required to coordinate with local governments, landowners, utilities, etc., the availability of backlog projects enhances the district's ability to add projects to letting if and when funds become available or if other projects are delayed. Super 2 Projects: Super 2 Projects enhance the ability to relieve congestion by providing passing opportunities on current 2-lane rural highways. These projects can usually be constructed within the existing right of way with only minimum utility adjustments and environmental impacts. In lieu of building a 4-lane divided highway, the Super 2 design is a viable method to enhance mobility and relieve congestion. Added Capacity Projects: These projects normally involve converting an existing 2-lane rural highway to a 4-lane divided facility. They usually involve the acquisition of right of way, which triggers additional public involvement and environmental work. These projects take longer to develop and by developing them as backlog projects, the district can have them closer to being ready to let if and when funding becomes available.
Childress	Rehabilitation and/or widening projects make good backlog PS&E. These projects are good because without a deadline for letting , it allows the designers more time to develop a good set of PS&E on projects that may have difficult design issues. These type projects also produce a longer construction schedule, which the contractors like.
Corpus Christi	The types of projects that make the most sense to develop as backlog are roadway widening projects that can be funded by Category 1 but require at minimum a PCE environmental document, safety projects (grade separations, bridge replacements, etc.) that also require a PCE level or higher environmental document, and of course higher priority mobility and/or other projects (added lanes, upgrade to freeway, etc.) that take a much longer lead time to complete the environmental process and may require acquisition of additional right-of-way (ROW).
Dallas	No backlog response.
El Paso	Overlay/Rehabilitation, toll-related, interstate, and regional freeway.

District	What types of projects would you develop as backlog?
Fort Worth	The preventative maintenance and rehabilitation projects are good candidates for backlog because typically they do not require a lot of detail PS&E development, the environmental documents tend to be BCE checklists and there is no set public involvement. These type projects can sit on the shelves for a few years and potentially the only thing that would need to be done to let them is to ensure the appropriate special provisions, etc. are up to date. Generally, the environmental document update would be to check the TxNDD website for species (currently only good for 6 months) and then to review if there have been any land use changes adjacent to the projects. They are basically quick and easy with no new ROW. Other projects aren't really good candidates because of the issue with ever changing interpretations of environmental regulations; sometimes a re-evaluation of the project can be challenging if there has been any changes (MTP's and STIP's are outdated quickly; especially in nonattainment areas). Continuous activities can be done assuming there have been no changes to the project and we can demonstrate there are activities (i.e., ROW acquisition) that have been ongoing since the environmental decision was given. The decision is only good for three years assuming no major changes to the project. Rural projects would be easier for backlogs due to the lack of issues with MTP's and limited issues with the STIP; however, they are harder to demonstrate continuous activity because they do not receive the same funding or attention that larger metropolitan areas do; so they can sit idle with nothing being accomplished. Off-system bridges may not be structurally deficient but can get agreements with locals whereas some SD bridges may not be able to get agreements. PM & Rehab (Cat. 1) easy to prepare and update if on the shelf for some time.
Houston	There are several backlog candidates (Corridors) that could be developed in the Houston Area if no constraints existed. Using the Top 100 Most Congested Roads in Texas, the list would include IH 45 North and South, US 59, IH 610, SH 288 and FM 1960 to name a few. In addition, to the top 100 projects, SH 36 and SH 146 would be a priority because of it being a Hurricane Evacuation Route.
Laredo	No response
Lubbock	A variety of projects ranging from sign upgrades to major freeway capacity projects should be developed for both urban and rural areas of the district. The costs of these projects should, also, vary in range based on the overwhelming needs of the infrastructure. This would allow for a quick pick of projects based on the available funding at a given instance. These costs should range from \$100,000 for sign up grades to \$50,000,000+ for urban freeways. In addition, there should be more latitude to the development of long range projects that usually require decades to develop.

District	What types of projects would you develop as backlog?
Lufkin	The Lufkin District will usually prepare rehabilitation projects for backlog on highways that have an identified need but aren't as high as priority as other funded work, or requires a large portion of the district's annual allocation such as Super2 designs.
Odessa	Heavy, Med Rehab and Light Rehab
Paris	Several types of projects make good candidate backlog projects. PM projects such as overlays can be easily generated and typically don't have many items that would need updating if they were accelerated into letting. Super 2 type projects take a little longer to develop but don't require an in-depth environmental process or additional ROW and can be accelerated easily.
Pharr	Specific rural mobility projects on major corridors and Specific urban mobility projects on major corridors.
San Angelo	No response
San Antonio	Rehab/widening and mobility
Tyler	I would develop safety projects, major rehab, Super 2, bridge replacements and maybe some minor mobility. Our typical Cat 1 and 11 funding allocations are used primarily to address minor Rehab and PM projects. Typically, these are projects that can be turned around in a relatively short time period with minimal staff. By developing larger Rehab, Safety, Super 2, bridge replacements, and minor mobility projects, we would be able to address needs that could not be addressed with our typical letting caps. This would allow us to have these larger projects that require more advanced planning work and lead time to be ready and available if additional funding became available. Although we have safety programs that allow us to address issues that are competitive statewide, we would also be able to address additional safety concerns that may not have competed as well, in a shorter time frame with new funding. To summarize, the current intent is to utilize Cat 1 and 11 funding to maintain our existing system. By having other types of projects ready and on the shelf, we are able to address other needs and priorities in an expedited manner and continue to utilize traditional funding for the maintenance of our system.
Waco	I prefer to develop a cross-section of many types of projects such as freeway widenings, interchanges, FM rehabilitations, and bridge replacements. This way you will have something available to add to the letting depending on the type and category of funding that comes available. You would not have to produce a backlog of PM or overlay work because that is relatively quick PS&E production that can be done when the funding becomes available.

District	What types of projects would you develop as backlog?
Wichita Falls	No response
Yoakum	Super 2. We do not have them in our district funding but these are very good projects if more funding becomes available.

Generally, the districts seem to prefer Rehabilitation projects (RER), because there is less likely of the plans having to be redone, and they can be slotted in at any time when funds come available. However, most also indicated that they would like to have a variety of project types in development.

2.2.5 Backlog Summary

Based on the analysis conducted in FY11 and the surveys conducted in FY 12, the consensus regarding backlogging is that it is necessary to have some projects ready or near ready to go if scheduled projects are delayed, bid prices come in low and 'leave money on the table', or if unanticipated funds come available. While some agencies develop a certain percentage of their annual letting (anywhere from 5–50%) as extra, others use a lead time approach, i.e., having x years of letting in the bank at any given time, for example, one year's worth of lettings ready to go.

An intriguing approach is used by Michigan DOT. They aim to let all their larger projects and 75% of their dollars in the first 6 months of the fiscal year. In this way, even if the more complex projects suffer a delay, they usually can still let it within the FY. They keep only routine projects, e.g., seal coats, for the second half of the FY. In effect, they are banking about 6 months of lettings.

The lead time approach seems to be the most feasible. It only develops projects that are already approved and funded, so there is little risk of cancellation. If about 1 year of lettings is in the bank at any time, there is low risk of rework or environmental re-do. It is highly unlikely that there will be enough underpricing to have extra funds for a whole year's program. It is also highly unlikely that one year's letting would be eaten up by a few large projects being delayed. Delays can be long, but again it is unlikely that all delayed projects would fall behind more than a year. Finally, if extra funds are anticipated, TxDOT would have almost 1 year to gear up, hire consultants, and re-direct resources to take advantage. So a one-year bank of projects appears to be a feasible backlog amount.

2.3 Task 12B. Project Development Staffing

In FY 12, CTR continued refining the PE staffing models developed in FY 11. The main subtasks accomplished in FY12 were the following:

- Collect and analyze additional data, including available P6 records, on project durations and TxDOT PS&E productivity.
- Develop models for estimating ADM (administration), AP (advance planning), PSP (PS&E production), and PSS (PS&E support) staffing.
- Submit initial models by November 30, 2011.
- Refine models for estimating PE needs and apply to TxDOT's PDP 2012 list of projects.
- Submit final models by July 31, 2012.

2.3.1 Review of FY11 Results

To estimate PE staffing needs, most state DOTs use a simplistic percentage-of-construction-volume method, typically estimating PE cost as 10–15% of construction cost. These percentages may be adjusted for individual projects based on project type, size, and provider, with % PE ranging from 6 to 20 percent. The PE cost so estimated is then converted to FTE (full-time equivalent) staff.

In addition to this method, TxDOT has used some rules of thumb. For example, a general estimate is that one FTE can produce $5 million per year in construction plans. Adjustments are considered for project type and provider. For bridge projects, TxDOT estimates $2.5 million construction per year per FTE, while for seal coats, it is $7.5 million per year per FTE. Consultants, who typically work on large-dollar mobility projects, are estimated to produce $6.5 million construction per year per FTE.

TxDOT projects are designated by Control-Section-Job numbers (CSJ). Multiple CSJs may be packaged as a Construction CSJ (CCSJ) for letting. PE costs at the CSJ and CCSJ level are tracked by TxDOT as "Function Code 100 series" in TxDOT's Financial Information Management System (FIMS).

In FY 11, CTR obtained data from TxDOT's Finance Division (FIN) on all CSJs let in FY 08–10, i.e., with letting dates between September 2007 and August 2010, a total of 3172 CSJs packaged and let as 2430 CCSJs. Table 2.7 is a summary of the number of CCSJs of each project type in that dataset.

Table 2.7: Project Types for 2008–10 TxDOT Lettings

Project Class	CSJs	Project Class	CSJs
Bridge Replacement (BR)	420	Restoration (RES)	69
Bridge Widen/Rehab (BWR)	88	Right-of-Way (ROW)	51
Convert Non-Freeway to Freeway (CNF)	5	Seal Coat (SC)	350
Interchange (INC)	33	Safety Treatment (SFT)	542
Landscape/Scenic Enhancement (LSE)	80	Traffic Signal (TS)	69
Miscellaneous Construction (MSC)	487	Upgrade Non-Freeway (UGN)	8
New Location Freeway (NLF)	6	Upgrade Freeway (UPG)	21
New Location Non-Freeway (NNF)	47	Utility (UTL)	16
Overlay (OV)	378	Widen Freeway (WF)	22
Rehab Existing Road (RER)	276	Widen Non-Freeway (WNF)	118

The small number of projects of some types (CNF, NLF) limits the ability to model their data. Noteworthy also is that 487 projects are classified as MSC, making it harder to distinguish unique project types statistically.

For each CSJ, the data included the hours and dollars charged to PE (overhead included). Total PE cost for these projects was $487.3 million, for 3,819,279 man hours. Figure 2.4 shows the distribution of hours to complete a CCSJ, with the most frequent observations (1349 CCSJs) being in the 100–1000 hours range. Of note is that 10 CCSJs had 0 hours, and 15 were found with 10 or less hours. At the other extreme, 68 CCSJs had 10,000 or more hours.

Figure 2.5 shows the distribution of cost per hour at the CSJ level. Average cost per PE hour was $127.58. However, the primary mode is in the $50–100 per hour range, suggesting that the typical cost lies in that range. There appears to be a secondary mode in the $200–500 per hour range, suggesting that there is a distinct set of projects with higher costs. Of concern is the fact that there are almost 600 CSJs with $0 per hour charged. Clearly, more attention needs to be paid to properly recording charges.

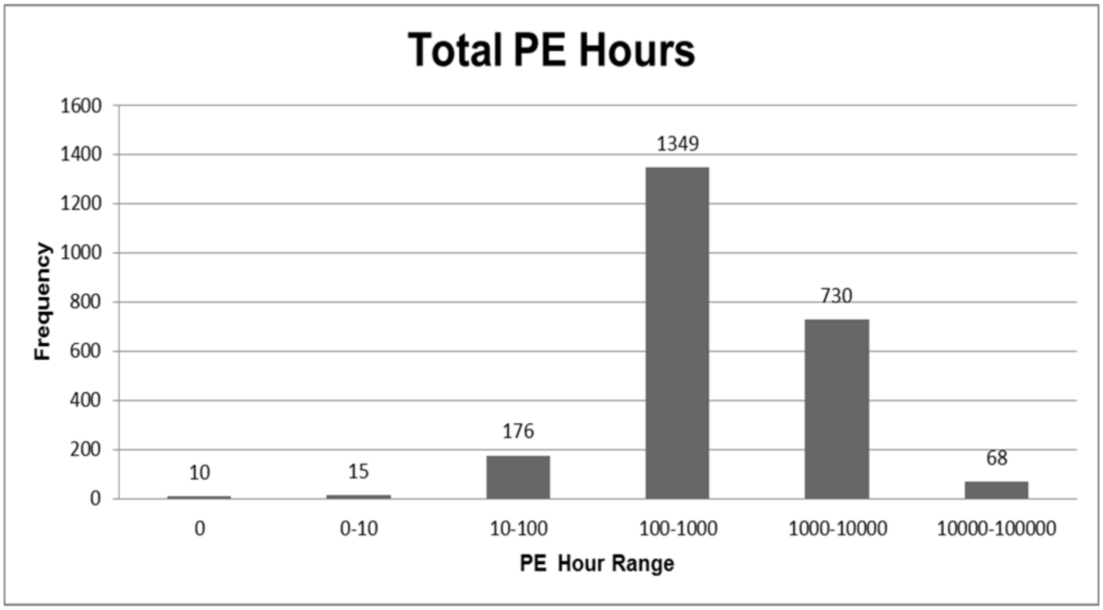


Figure 2.5: Distribution of PE Hours for TxDOT CCSJs let in FY 08–10

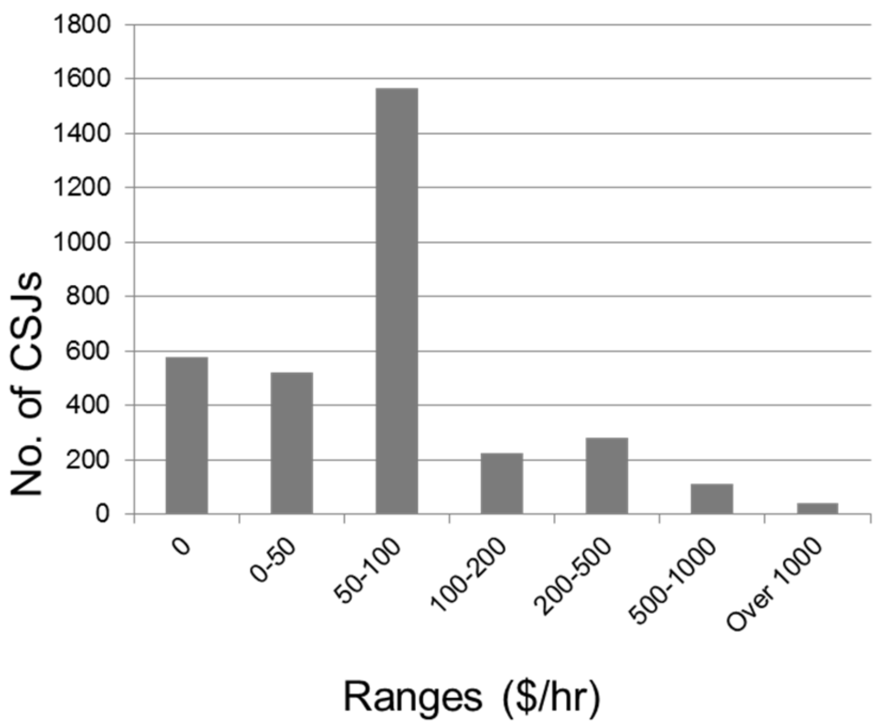


Figure 2.6: Distribution of PE Cost/Hour at CSJ Level

To estimate future staffing needs, it is necessary to estimate PE costs at the project level. In FY 11, effort was focused on analyzing the data at the CCSJ level. Of the 2430 CCSJs for which data was obtained, 90 had zero charges, and these were removed from further analysis.

CTR developed initial models for estimating PE staffing at the project level using project type and construction cost as predictors. A model of the following form was proposed:

PE Cost (or Hours) = F{Construction Cost, Location, Project Type}

The data distributions were observed to be non-normal (as with many phenomena), so in order to satisfy conditions for statistical analysis, a log transform was done:

$$\mathbf{Log_{10}PE\ Cost\ (or\ Hours) = (Constant\ A) + B^{*}\ Log_{10}Construction\ Cost + Project\ Type\ Factor + Location\ Factor}$$

PE Hours and Cost and Construction Cost are continuous variables, while Project Type and Locations are Binary (e.g., BR is present (=1) or absent (=0), etc., and Location is Metro (Y=1, N=0), Urban or Rural). Stepwise regression was carried out in the SPSS Statistical Package, whereby variables were entered in order of significance, and removed if no longer significant. Table 2.8 gives the result for PE Cost:

Table 2.8: SPSS Statistical PE Cost Model for 2340 FY 08–10 CCSJs

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
15	.737[o]	.544	**.541**	.46973

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
15	(Constant)	1.612	.126		12.788	.000
	Const_Costs	.563	.019	.504	30.328	.000
	OV	-.901	.041	-.451	-22.194	.000
	SC	-1.059	.054	-.331	-19.748	.000
	BR	.158	.041	.080	3.840	.000
	WNF	.170	.056	.050	3.031	.002
	Metro	.103	.032	.048	3.230	.001
	LSE	-.548	.066	-.137	-8.342	.000
	RES	-.518	.068	-.118	-7.566	.000
	RER	-.354	.043	-.158	-8.243	.000
	SFT	-.324	.041	-.169	-7.832	.000
	MSC	-.232	.041	-.126	-5.720	.000
	TS	-.302	.069	-.072	-4.384	.000
	Rural	-.056	.022	-.040	-2.584	.010

The model can be read as

Log (PE Cost) = 1.612 + 0.563 Log (Constr. Cost) + 0.158 BR + 0.17 WNF – 0.548 LSE – 0.518 RES – 0.354 RER – 0.324 SFT – 0.232 MSC – 0.301 TS - 0.901 OV - 1.059 SC + 0.103 Metro – 0.056 Rural

The project types not listed are the pool group. Thus, the pool is "Other project type, in an Urban County." The numbers for Metro and Rural indicate that Metro projects are 10^0.103 = 27% more costly, and Rural projects are 10^-0.056 = 88% of the cost of Urban projects. A positive coefficient for a specific project type indicates that that type is more costly than the pool, while a negative coefficient indicates it is less costly. The adjusted R-squared of the model is 0.541, indicating that PE cost is only partially reflected by construction cost, project type, and location. The standard error is 0.470, meaning that for 68% confidence in estimate (one standard deviation on each side of mean), the natural PE cost estimate is multiplied or divided by 10^0.47 = 2.95.

In additional analysis, it was found that there was some interaction between project type and construction cost, i.e., the model for some project types had different trend line slopes. However, these differences were so small that the simpler model without interaction (presented above) is preferred.

In FY 11, the above PE cost model was used to develop a preliminary estimate of district PE staffing needs. TxDOT had a task force working on developing a 4-year program of lettings for the districts. A preliminary version was provided to the research team in late 2010. It was a list of CSJs by district, with data on project type, estimated construction cost, and estimated letting date. It was observed that the projects petered out in 2013, meaning that the draft work plan was missing some projects from 2014. The total construction volume for the period August 2010 through October 2013 was $12,595,251,875, or about $12.6 billion.

The PE cost model was applied to this list of projects to estimate district PE expenditure for the draft work plan. A total PE cost for each project was calculated. Next, an assumption had to be made as to when that PE effort is expended. In general, districts are required to submit projects to Austin for review 3 months before letting, so the PE completion date was estimated as 3 months before the let date.

Then, various project durations were assumed. The PE cost was spread evenly over the duration (a simplification, but a reasonable one, since expenditure follows a 'bell' curve, and a summation of the averages equates to the expected average). Figure 2.6 shows the results for a fixed duration of 12 months for all projects. Different durations gave slightly different profiles, but the peaks and valleys did not vary a lot.

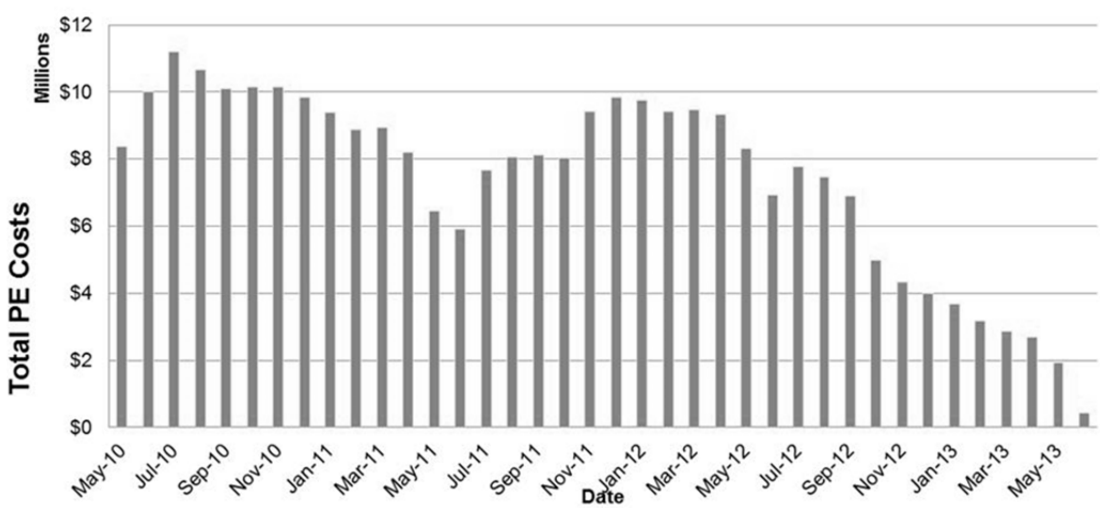


Figure 2.7: Estimated PE Expenditures, TxDOT Draft 4-Year Work Plan

Clearly, the fade-out that begins around October 2012 is due to the missing projects in 2013. These results show that the peak in PE effort is around \$10 million per month in the period November 2011 to April 2012. The shoulder appears to be about \$8 million per month. Converting cost to FTEs required data on average cost per FTE, but straight average salary could not be used without checking on FTE availability and effectiveness.

To address these data needs, a questionnaire was developed and sent to the districts. Three key questions were asked:

1. Availability: How many staff did you have in FY 08–10 in each of the following categories: Advanced Planning (AP), PS&E Production (PSP), PS&E Support (PSS), Consultant Management (CM), Toll/CDA projects (Toll), and Other Administration (ADM)? (Note: These work categories were established by a TxDOT Task Force).
2. Effectiveness: What percentage of time did each of those functions spend on projects that didn't go to letting?
3. Estimation check: For a hypothetical annual program of work (ranging from \$10 million to \$1 billion), how many staff in each of those functions would be needed?

The questionnaire was sent out in August 2011 and the data received was analyzed in FY12.

2.3.2 FY12 Work: District Questionnaire Results and Analysis

District Directors of Transportation Planning and Development (TP&D) responded to the August 2011 questionnaire. Table 2.9 is a summary of their responses to Question 1—how many FTEs the district had in FY 08–10 (on average) in the respective categories?

Table 2.9: FTEs in Districts in FY 08–10

District	AP	PSP	PSS	ConsltMgt	Toll/CDA	OtherADM	FTEs
Abilene	5	9	2.33	0.33	0	4	**20.667**
Amarillo	3	10	2	0	0	4	**19**
Atlanta	5	14	2	0	0	7	**28**
Austin	15	28	8	0	1	17	**69**
Beaumont	4	23	2	1	0	3	**33**
Brownwood	3	8	1	0	0	2	**14**
Bryan	5	20	4	1	0	5	**35**
Childress	1	9	2	0	0	1	**13**
Corpus Christi	10	20	6	2	0	4	**42**
Dallas	22	75	22	46	5	41	**211**
El Paso	30	32	1	13	11	13	**100**
Fort Worth	4	37	13	3	6	6	**69**
Houston	48	142	21	15	0	17	**243**
Laredo	6	13	7	6	0	12	**44**
Lubbock	2	13	1	1	0	3	**20**
Lufkin	5	12	2	2	0	6	**27**
Odessa	2	5	3	1	0	2	**13**
Paris	4	21	2	1	0	2	**30**
Pharr	6	34	7	6	0	1	**54**
San Angelo	1	11	8	0	0	1	**21**
San Antonio	11	25	4	1	4	0	**45**
Tyler	7	8	4	1	1	5	**26**
Waco	3	24	10	4	0	7	**48**
Wichita Falls	2	10	5	1	0	2	**20**
Yoakum	0.25	13	2	0.25	0	7	**22.5**
Total	**204**	**616**	**141**	**106**	**28**	**172**	**1,267**
% of Total	16.1%	48.6%	11.2%	8.3%	2.2%	13.6%	

A total of 1267 FTEs were reported, with 16% in Advance Planning (AP), 49% in PS&E Production (PSP), 11% in PS&E Support (PSS), 8% in Consultant Management, 2% on Toll/CDA projects, and 14% in Other Administration including district management. Houston, Dallas, and El Paso reported the largest numbers of FTEs, with Childress, Odessa, and Brownwood the lowest.

One objective in collecting this data on actual district staffing was to compare the PE charges by each district to the number of staff and letting volumes. The PE costs, hours, and letting volumes for the districts for the FY08–10 period were computed, as shown in Table 2.10.

Table 2.10: Summary Statistics for Districts in FY 08–10

District	3YrPE$	3YrHrs	3Yr$/Hr	Hrs/Yr/FTE	3YrLet$	FTEs
Abilene	5,336,852	39,368	135.56	634.97	107,872,004	21
Amarillo	5,957,485	88,085	67.63	1,545.35	175,446,177	19
Atlanta	8,061,091	125,318	64.33	1,491.88	181,872,401	28
Austin	28,444,743	131,644	216.07	635.96	428,048,658	69
Beaumont	16,512,883	103,291	159.87	1,043.34	321,081,768	33
Brownwood	2,918,112	50,578	57.70	1,204.24	81,288,921	14
Bryan	14,193,650	123,855	114.60	1,179.57	222,930,515	35
Childress	3,571,675	50,689	70.46	1,299.72	79,995,193	13
Corpus Christi	16,886,505	166,251	101.57	1,319.45	285,501,376	42
Dallas	79,653,856	508,140	156.76	802.75	1,622,987,635	211
El Paso	10,310,583	103,772	99.36	345.91	121,327,504	100
Fort Worth	22,364,678	170,412	131.24	823.25	602,424,677	69
Houston	76,577,239	892,865	85.77	1,224.78	1,058,368,149	243
Laredo	21,204,693	101,164	209.61	766.39	217,669,379	44
Lubbock	11,221,314	93,741	119.71	1,562.35	244,645,135	20
Lufkin	7,550,952	47,817	157.91	590.33	149,025,023	27
Odessa	4,553,102	63,949	71.20	1,639.72	167,941,121	13
Paris	10,285,618	80,257	128.16	891.74	250,939,707	30
Pharr	22,216,330	144,416	153.84	891.46	387,910,575	54
San Angelo	2,788,201	46,125	60.45	732.14	81,879,584	21
San Antonio	58,567,487	249,024	235.19	1,844.62	389,924,049	45
Tyler	13,626,376	124,021	109.87	1,590.01	353,093,213	26
Waco	29,214,329	169,737	172.12	1,178.73	690,838,763	48
Wichita Falls	8,783,925	76,318	115.10	1,271.97	176,625,133	20
Yoakum	6,462,878	68,442	94.43	1,013.96	181,669,158	23
Totals	487,264,559	3,819,279	128		8,581,305,819	1267

This table shows that there are wide differences among districts in charges and outputs. For example, PE cost per hour varies from $235.19 in San Antonio to $57.70 in Brownwood. Hours recorded per year per FTE vary from 1845 in San Antonio to 346 in El Paso. These differences suggest that there may be some issues with the data, including the following:

1. The charges recorded may not be all in-house, but may include consultant charges.
2. Districts may not be consistent in recording staff time on non-letting projects or other functions.
3. The staff reported by the districts may not be exact.
4. The projects let in the 3 year study period (FY08–10) may have spanned different periods and may not represent district performance.

To illuminate some of these discrepancies, various data plots were studied. Figure 2.7 shows District Lettings for the 3 year period versus Total Staff. The trend line indicates that the districts averaged just over $6 million per FTE for 3 years, or about $2 million per FTE per year. Dallas and Waco are above the line, while Houston and El Paso are below.

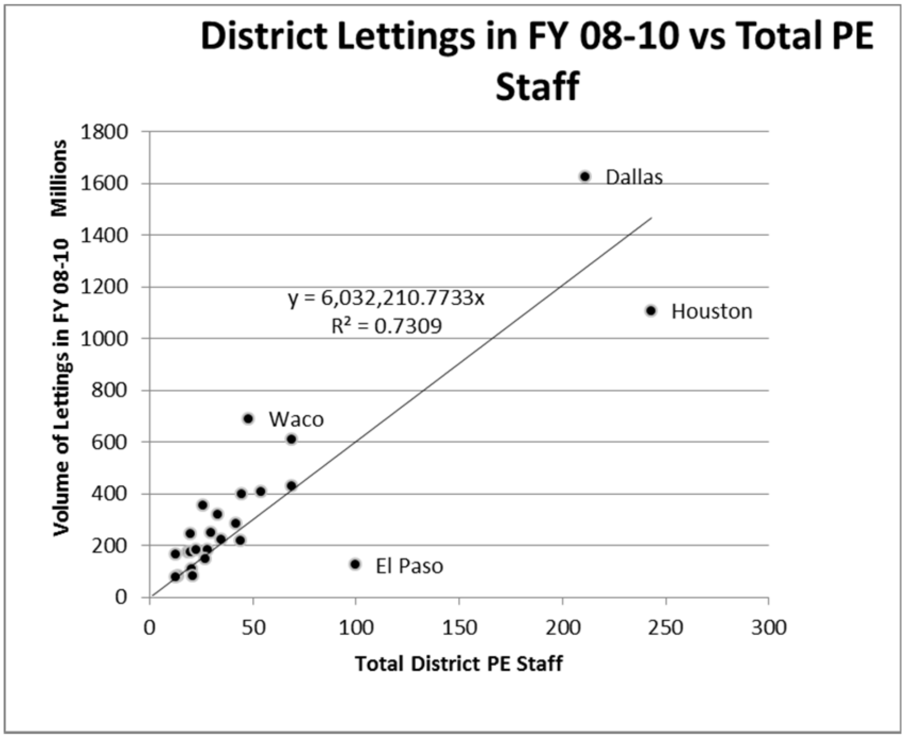


Figure 2.8: District Lettings for FY 08–10 versus Total Staff

Figure 2.8 shows District PE Charges for the 3 year period versus Total Staff. The trend line indicates that the districts averaged just over $350,000 per FTE for 3 years, or about $117,000 per FTE per year. San Antonio is way above the line, while El Paso is far lower. It must be noted that very few staff in TxDOT earned $117,000 per year in that period, suggesting that some of these charges may be from consultant projects.

Figure 2.9 shows District PE Charges for the 3 year period versus 3-year Letting Volume. The trend line indicates that the districts averaged just over 5.52% for 3 years. Now it is seen that San Antonio is the most expensive, and Fort Worth is the least.

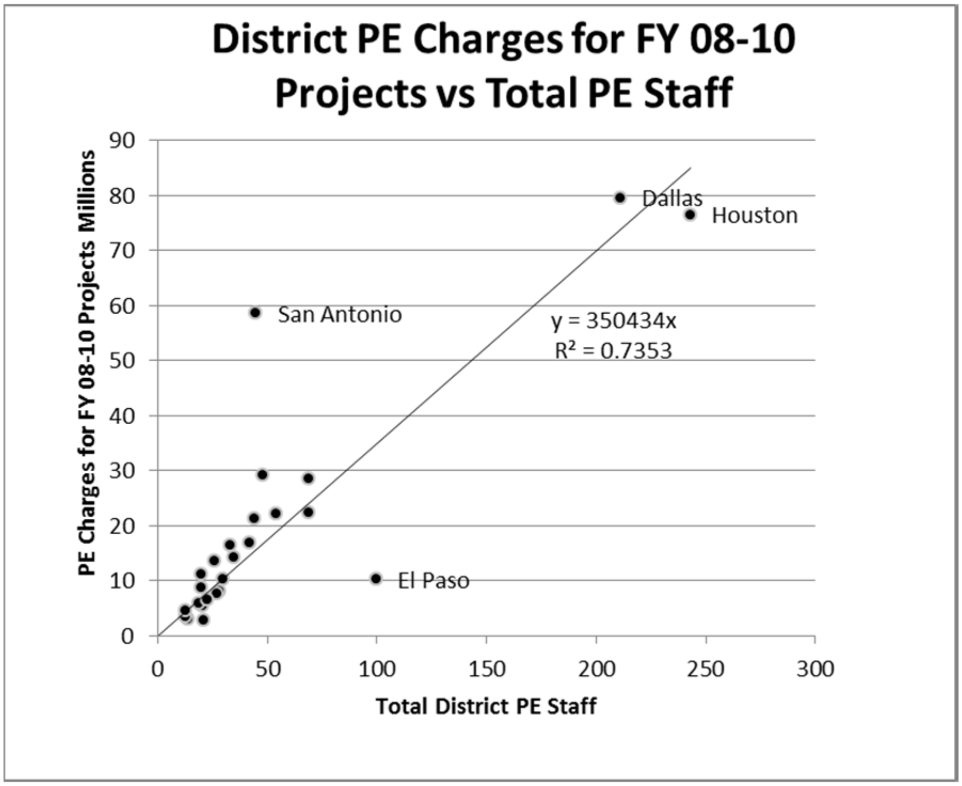


Figure 2.9: District PE Charges for FY 08–10 Lettings versus Total PE Staff

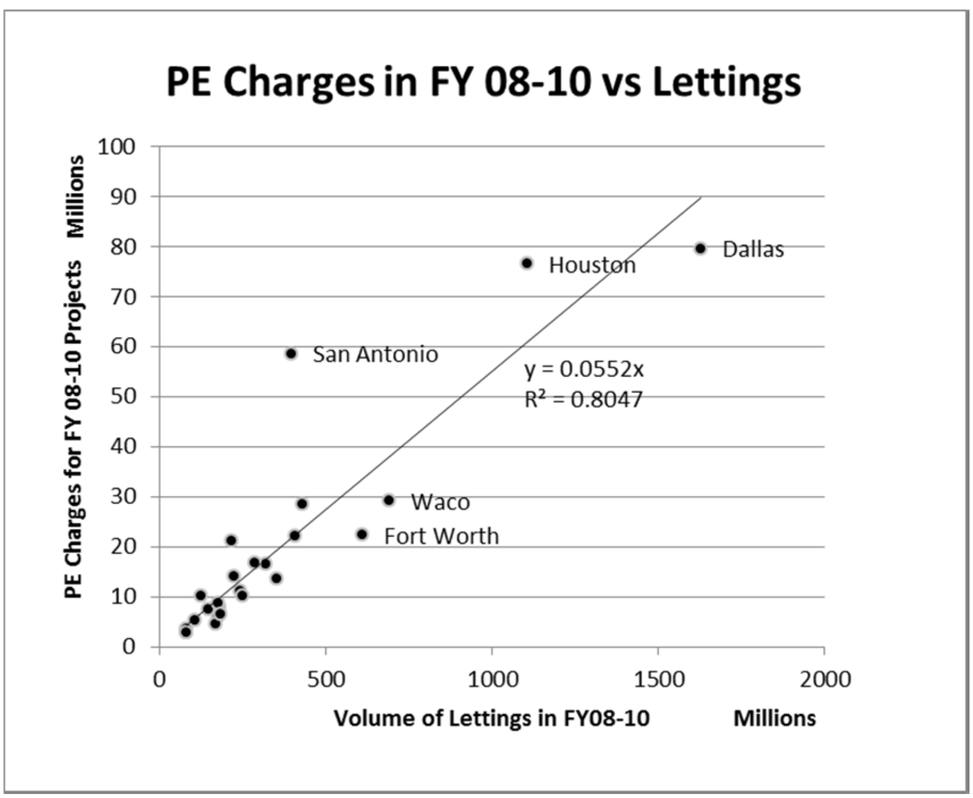


Figure 2.10: District PE Charges versus FY 08–10 Lettings

What these charts indicate is that PE charges in the districts are a mix of consultant and in-house data. The research team attempted to separate the two by requesting additional information on the projects. However, it was learned that the districts are inconsistent in how consultant charges are assigned to projects, so it is not feasible to separate the two. However, it was also learned that the hours charged to projects are all in-house hours, since consultant charges are not converted to hours. Therefore, the focus of the analysis shifted to studying the hours charged.

Figure 2.10 is a plot of PE costs charged versus hours charged. The trend line shows an average cost of $114.17 per hour. San Antonio is the highest, at $235.19 per hour, with Brownwood the lowest at $57.70 per hour. Surely there is not such a large discrepancy in salaries between Brownwood and San Antonio, suggesting that the true cost per hour is nearer to Brownwood's figure and that San Antonio's figure is affected by consultant charges.

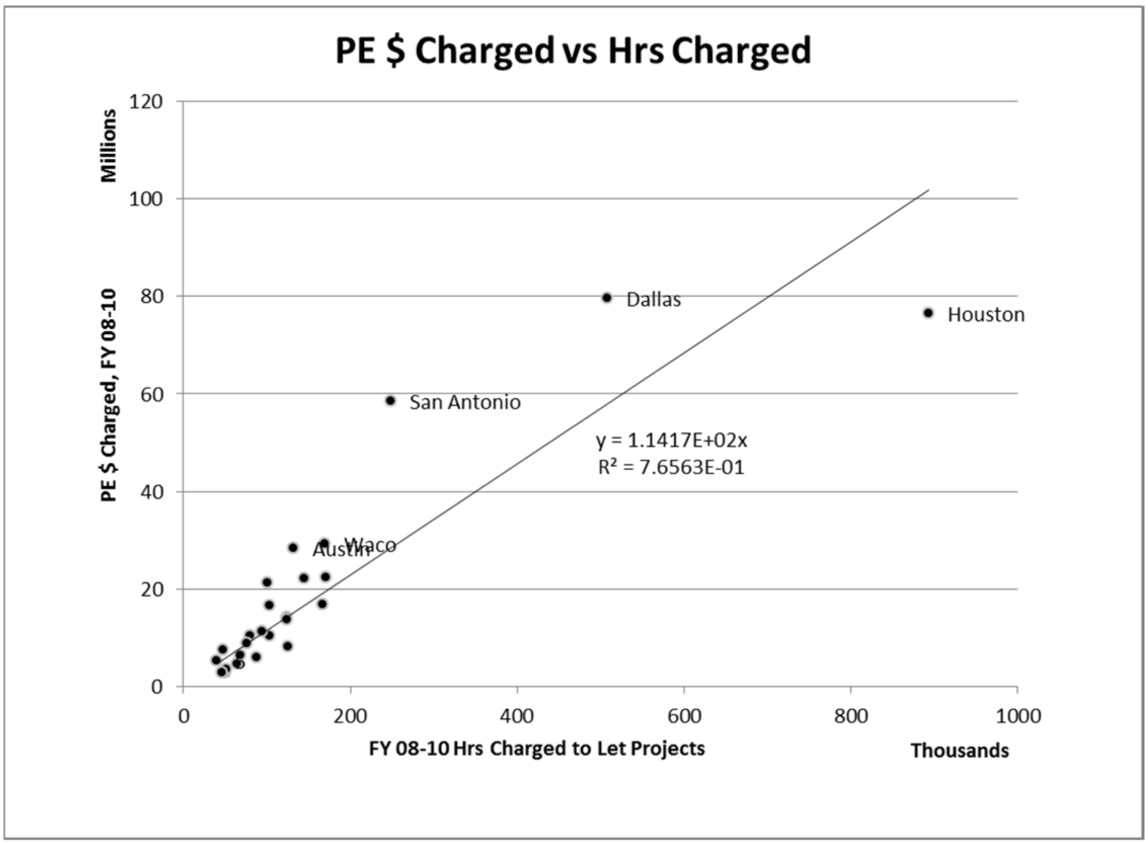


Figure 2.11: PE Charges versus PE Hours for Projects Let in FY 08–10

Figure 2.11 is the same data presented in a comparative way as a bar chart. It is seen that several small districts have costs at $70 per hour or less, while a few have costs over $200 per hour. These numbers are generally consistent with the level of consultant work in the districts, indicating that in-house PE costs are nearer to $60–70 per hour.

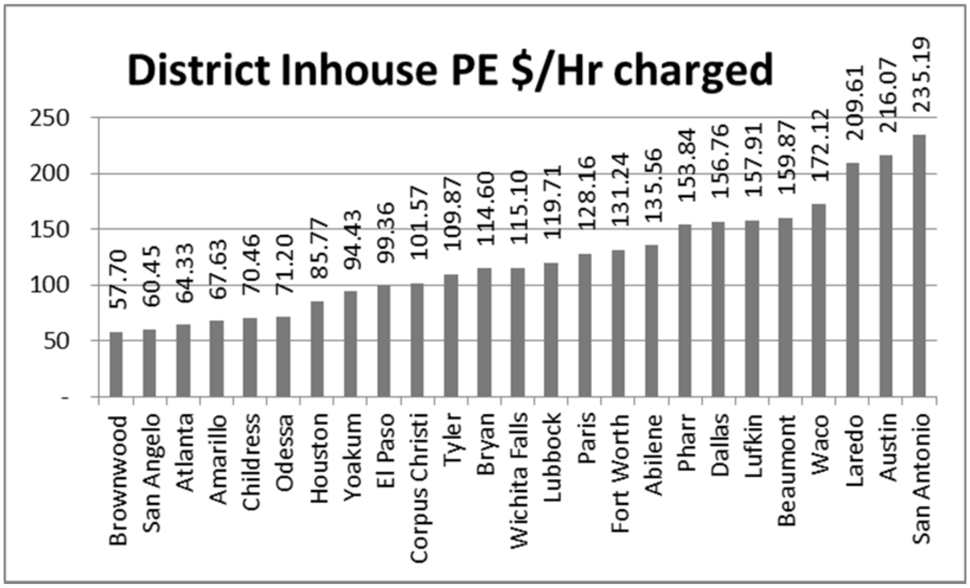


Figure 2.12: Average PE Charges per Hour for FY 08–10 Lettings—All Districts

However, low cost does not necessarily imply effectiveness. Figure 2.12 shows the hours charged per year per FTE for the 3 years of lettings studied. San Antonio is the highest at 1845, while El Paso is lowest at 346. The mean is 989, and the median is 1180. (Note: the actual PE work would have been done over some period prior to letting. The assumption made here is that in a steady state the projects let per year equate to the charges per year).

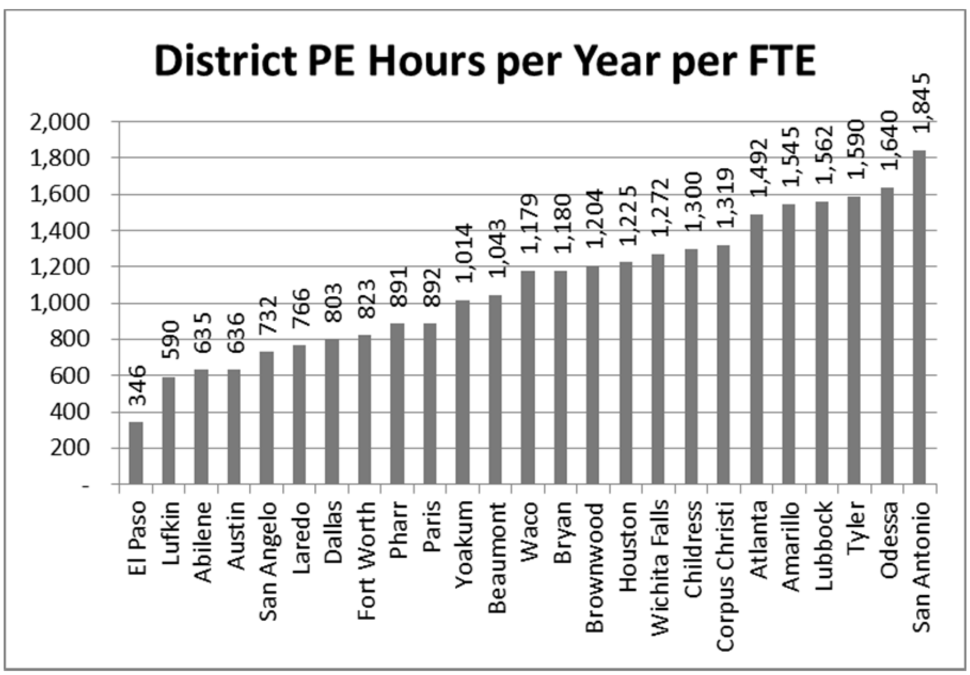


Figure 2.13: Average PE Hours Charged per Year for FY 08-10 Lettings—All Districts

Two insights can be drawn from these numbers.

1. There is high variability in the hour charges recorded by the districts. There may be errors in the way hours are recorded, or in the number of staff being counted as PE staff.
2. A significant amount of district staff charges may not be showing up in let projects. Data was not available on whether the low districts had higher administrative charges.

2.3.3 PE Staff Availability and Effectiveness

To determine a reasonable factor for converting hours to FTEs, data was obtained from TxDOT's Human Resources Division (HRD) on typical non-work hours, and consequent availability of staff. Table 2.11 is a summary of the HRD numbers—given that staff are available 1728 hour per year. A rule of thumb in human resource management is that workers spend about 70% of available time on effective work, and about 30% attending to non-project issues. Thus, 70% of 1728 is 1210 hours, leaving 518 for meetings and other work that does not appear in lettings. These figures can be rounded to 1225 and 503 respectively.

Table 2.11: Hours available for FTEs, per Human Resources Division

Maximum hours available annually	2080
Typical vacation time annually	125
Typical sick leave time annually	99
Scheduled holidays annually	112
Mandatory training annually	16
Available work hours annually	1728
Effective hours annually (~71%)	1225
Time in meetings and non-letting projects	503

2.3.1 District Charges and PE Costs

In FY 11 and early FY 12, when the research team examined PE Costs, some anomalies were noted in the data. For example, the dollar charges per hour in different function codes and different districts were highly variable (See Figure 2.11). To understand how PE expenditures are recorded, the research team obtained data on all FY 09–11 Function Code 1xx charges (FIMS Segment). Figure 2.13 shows the relative distribution.

A total of $958.6 million was expended, of which 62% were Services. Indirect Charges totaled 6%, and Residency Overhead and "Rest" were 6% and 3% respectively. Salaries to PE staff were 23% or $223,450,765, which averages to $58,787 per FTE, assuming that roughly the same number of FTEs as the 1267 in FY 10 were on payroll in FY 09–11.

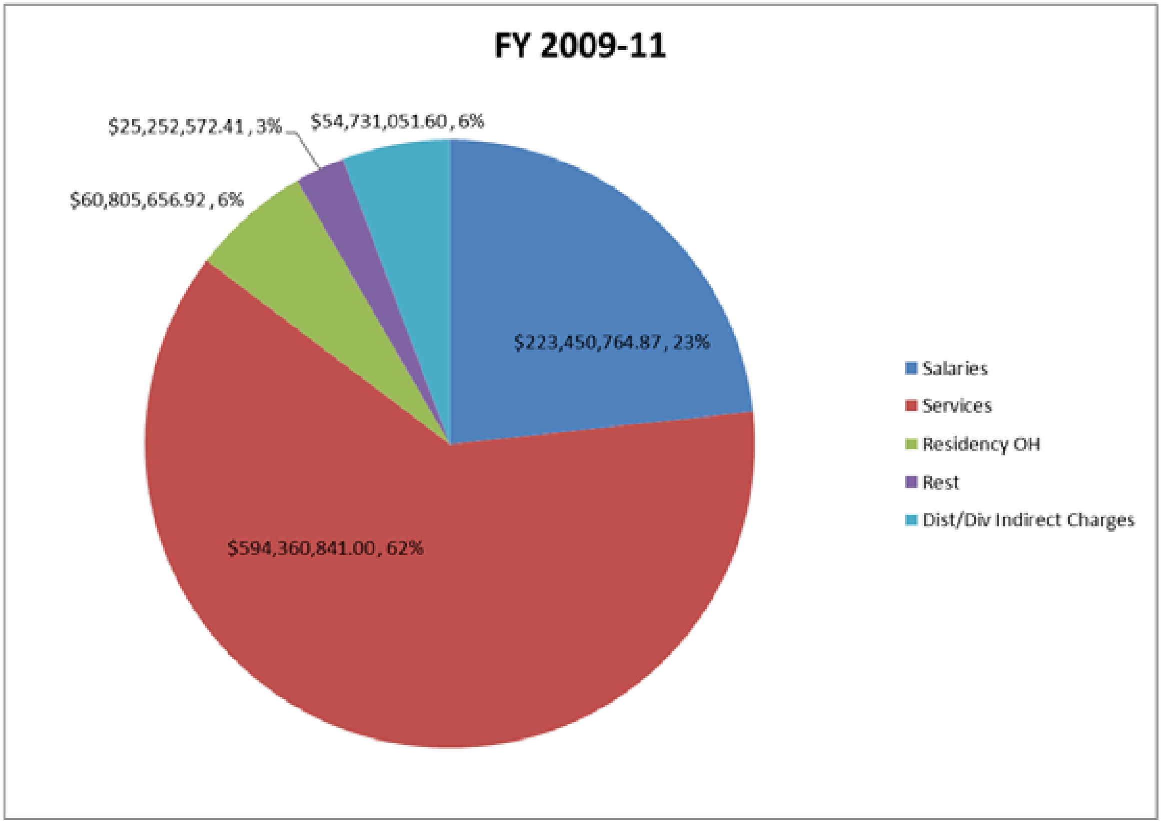


Figure 2.14: Distribution of Charges to Function Codes 1xx for FY 09–11

Residency Overhead and Indirect Costs are shown in Figure 2.14.

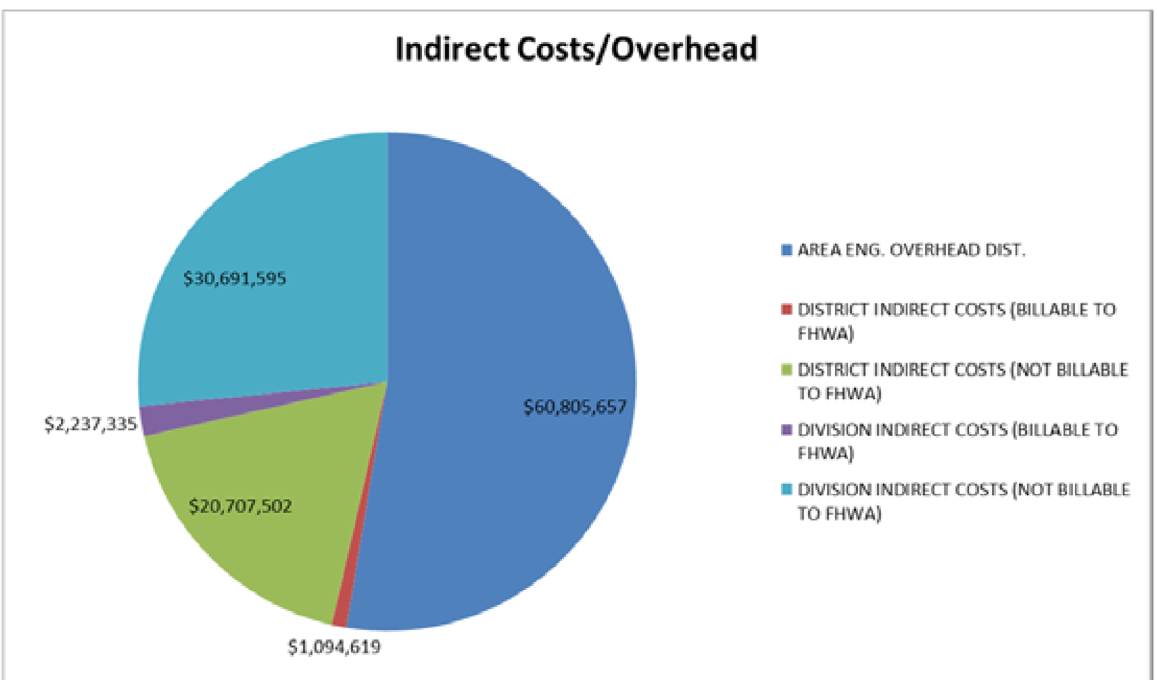


Figure 2.15: Indirect Costs and Residency Overhead for FY 09–11

Figure 2.15 show the breakdown on the $594 million expended on Services. Engineering Services comprise 70% of that total.

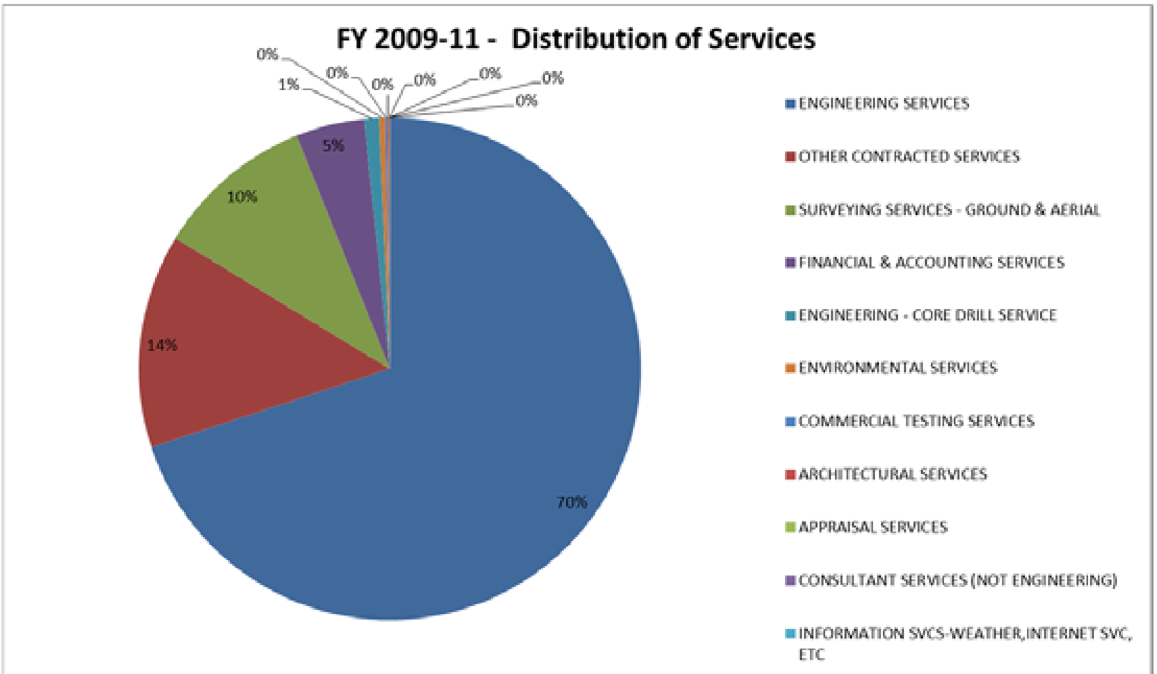


Figure 2.16: Distribution of Expenditures on Services for FY 09–11

These figures provide no further clarification of the observed differences in cost by district. Instead, the research team deferred to a study being conducted by Texas State University on the costs of In House and Consultant engineering, and focused instead on PE hours and staffing estimation.

2.3.2 CSJ PE Hours Model

In FY 11, models were developed at the CCSJ level to estimate PE costs for letting a package of projects. However, when the TxDOT Task Force developing the department's 4-year work plan compiled a new list of projects in late 2011, it was noted that most of the projects were CSJs. Therefore, the research team developed a new model of PE hours at the CSJ level as functions of CSJ construction cost and project type. This time, interaction between project type and construction cost was considered, allowing each project type to have its own slope. Table 2.12 shows the result.

Table 2.12: SPSS Statistical PE Hours Model for 3172 FY 08–10 CSJs

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
12	0.60058989	0.36070821	0.3577127	0.51367355

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
12	(Constant)	-0.33418773	0.12017974		-2.78073274	0.0054633
	LogConstCosts	0.52233087	0.02003214	0.51050234	26.0746384	3.977E-133
	OV_CC	-0.08033834	0.00534492	-0.2584041	-15.0307708	5.3346E-49
	BR	0.14007441	0.03025112	0.08038268	4.63038709	3.8321E-06
	WNF_CC	0.03707636	0.0079445	0.08147207	4.66692326	3.2149E-06
	WF	0.4890895	0.11354917	0.0702576	4.30729261	1.7149E-05
	SC	-0.27134238	0.04904679	-0.09101654	-5.53231641	3.4808E-08
	RES_CC	-0.0381912	0.01033777	-0.05981656	-3.69433839	0.00022507
	LSE_CC	-0.27904644	0.10719987	-0.40389312	-2.6030482	0.00929321
	MSC_CC	-0.13927012	0.04945333	-0.47640601	-2.81619286	0.00489686
	UPG	-0.29352932	0.11423884	-0.04120404	-2.56943544	0.01024256
	MSC	0.7507574	0.29163303	0.43661155	2.57432224	0.01009938
	LSE	1.36852842	0.59297835	0.35918722	2.30788934	0.02108463

This model can be read as

Log (PE Hours) = - 0.3342 + 0.5223*Log(ConstrCost) + 0.1401*BR +1.3685*LSE - 0.2791*LSE*Log(ConstrCost) + 0.7508*MSC - 0.1393*MSC*Log(ConstrCost) - 0.0803*OV*Log(ConstrCost) - 0.0382*RES*Log(ConstrCost) - 0.2713*SC- 0.2935*UPG + 0.0371*WNF*Log(ConstrCost) + 0.4891*WF

The project types not listed are the pool variable. Note that the location variable was not found significant, meaning that project PE hours are statistically similar across all districts. A positive coefficient for a specific project type indicates that that type requires more hours than the pool, while a negative coefficient indicates it requires less. A positive slope coefficient for a specific project type indicates that the hours for that type increase faster with project size than the pool projects, while a negative coefficient indicates it increases more slowly.

The CCSJ model developed in FY 11 for PE Hours was

Log (PE Hours) = 0.071 + 0.459 Log (Constr. Cost) + 0.154 BR + 0.327 WNF + 0.230 NNF + 0.260 INC– 0.214 LSE – 0.211 RES – 0.063 SFT - 0.471 OV – 0.611 SC

The relevant coefficients for each project type for the CCSJ PE Hours model developed in FY 11 and the new CSJ PE Hours model are compared in Table 2.13.

Table 2.13: FY 08–10 PE Hours Models for CSJs and CCSJs

	CSJ Model		CCSJ Model	
Model Adjusted R-Square	0.358		0.431	
Model Standard Error	0.5137		0.4305	
Project Type	**Intercept**	**Slope**	**Intercept**	**Slope**
Bridge Replacement (BR)	-0.1941	0.5223	0.225	0.459
Interchange (INC)	-0.3342	0.5223	0.331	0.459
Landscape/Scenic Enhance (LSE)	1.0343	0.2432	-0.143	0.459
Miscellaneous Construction (MSC)	0.4166	0.3930	0.071	0.459
New Location Non-Freeway (NNF)	-0.3342	0.5223	0.301	0.459
Overlay (OV)	-0.3342	0.4420	-0.400	0.459
Restoration (RES)	-0.3342	0.4841	-0.140	0.459
Seal Coat (SC)	-0.6056	0.5223	-0.540	0.459
Safety Treatment (SFT)	-0.3342	0.5223	0.008	0.459
Upgrade Freeway to Standards (UPG)	-0.6277	0.5223	0.071	0.459
Widen Freeway (WF)	0.1549	0.5223	0.071	0.459
Widen Non-Freeway (WNF)	-0.3342	0.5594	0.398	0.459
Other Project Types, including BWR, CNF, NLF, RER, TS and UGN.	-0.3342	0.5223	0.071	0.459

These results show that at the CSJ level there is higher variability in the data, giving lower model R-square and higher standard error. The slopes are also generally steeper at the CSJ level, indicating that if PE staffing is estimated at the individual CSJ level, the aggregate estimate will higher than if estimated at the bundled CCSJ level. Because projects are executed in the development phase at the CSJ level, this difference is critical to estimating staffing needs. Thus, the CSJ model is preferred over the CCSJ model.

The CSJ PE Hours model is plotted for the valid range of project cost for each project type in Figure 2.16. The same plots are shown in more detail for small projects, in Figure 2.17. The “Other” line represents projects that were not found to be statistically different, and it is to be noted that this includes Bridge Widening/Rehabs, Convert Non-Freeway to Freeway, Interchanges, New Location Freeways, New Location Non-Freeways, Safety Treatments, Traffic Signals, and Upgrading Non-Freeway to Standards. However, referring back to Table 2.3, it is seen that some of these project types are few and rare. It is recommended that the WF model be used for CNF, INC, and NLF projects. The “Other” model is suitable for less complex projects such as BWR, NNF, SFT, TS, and UGN projects.

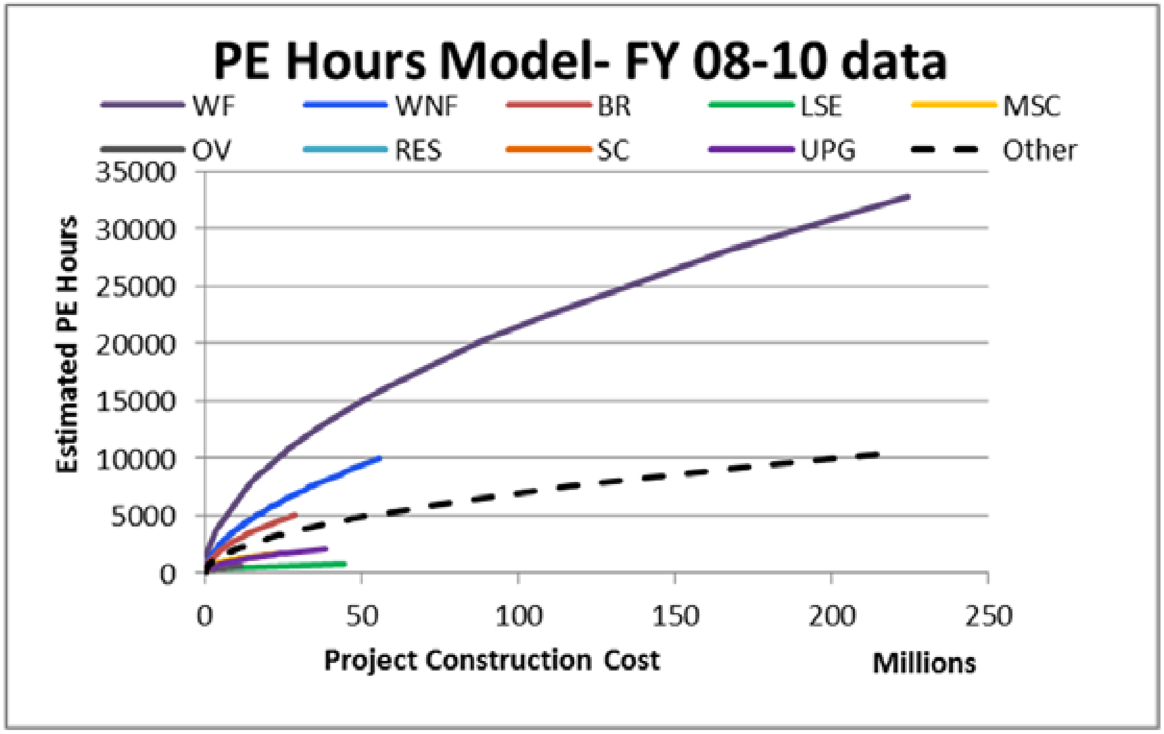


Figure 2.17: PE Hours Model for CSJs Let in FY 08–10

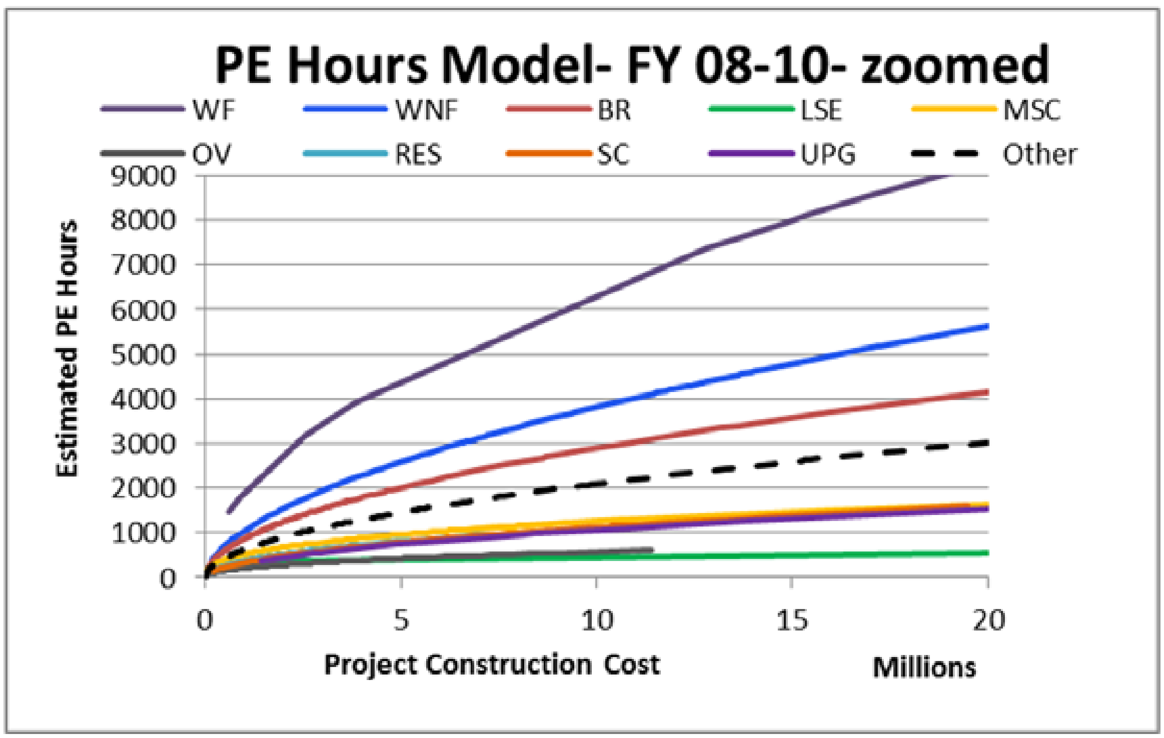


Figure 2.18: PE Hours Model for CSJs Let in FY 08–10, for Project Size <$20 Million

2.3.3 District Staffing at the Function Level

The PE hours model estimates the total hours in all function codes to complete a CSJ. Table 2.14 shows all the functions in a project to which PE hours can be charged. The districts are interested in the estimation of staff for the previously identified primary PE functions (Advance Planning, PS&E Production, PS&E Support, etc.), so it was necessary to determine to which codes each PE function typically charge their time.

Table 2.14: TxDOT PE Function Codes

Function Code	Function Description
102	Feasibility Studies
110	Route and Design Studies
120	Social, Economic and Environmental Studies and Public Involvement
126	Donated Items or Services
130	Right-of-Way Data (State or Contract Provided)
145	Managing Contracted or Donated Advance PE Services. Also includes all costs to acquire the consultant contract(s) and services Applicable to advance PE, Function Codes 102 - 150. Advance PE are activities in Function Codes 102 through 150.
146	Rework by TxDOT of complete consultant plans on advance PE projects. Advance PE are activities in function codes 102 through 150.
150	Field Surveying and Photogrammetry
160	Roadway Design Controls (Computations and Drafting)
161	Drainage
162	Signing, Pavement Markings, Signalization (Permanent)
163	Miscellaneous (Roadway)
164	Managing Contracted or donated PS&E PE Services. Also includes all costs to acquire the Consultants Contract(s) and Services applicable to PS & E, Function Codes 160 - 190. PS&E PE are activities in function code 160 through 190.
165	Traffic Management Systems (Permanent)
166	Rework By TxDOT Of Completed Consultant Plans on PS&E projects. PS&E PE are activities in function codes 160 through 190. Rework Segment 76 FCs 160-190 for metric conversion. For reworking existing PS&E to metric units on projects already into plan preparation.
169	Donated Items or Services
170	Bridge Design
180	District Design Review and Processing
181	Austin Office Processing (State Prepared PS&E)
182	Austin Office Processing (Consultant Prepared PS&E)
190	Other Pre-letting date Charges, Not Otherwise Classified.
191	Toll Feasibility Studies
192	Comprehensive Development Agreement Procurement
193	Toll Collection Planning

After discussions with district staff, the following general assignment was developed:

- Advance Planning (AP)
  - Function Codes 102-149*
- PS&E Production (PSP)
  - Function Codes 160-170 except 164, 166, 169
- PS&E Support (PSS)
  - Function Codes 150*, 180-190
- Administration (ADM)
  - Function Codes 164, 166, 169, 191-193

  *Note: Function 150 has been defined as both AP and PSS. In this analysis, it is treated as PSS.

The FY 08-10 CSJ data was analyzed to determine whether valid models could be created at the function level using the same predictors, project cost and type, for PE hours. Table 2.15 is a summary of the relevant results. The Adjusted R^2 was very low for PSP and PSS, and all the standard errors were high compared to the model for Total PE Hours (0.51). The models for AP and ADM found that project location, namely, in a metro, urban, or rural county, influences PE hours.

Table 2.15: Summary of Models for Hours at the Function Level

Modeled Function	Adj R2	Std Error	Location Multiplier	
			Metro	Rural
ADM	0.3007	0.8460	1.6560	0.6396
AP	0.4037	1.4193	1.0000	1.2758
PSP	0.2241	1.0974	1.0000	1.0000
PSS	0.1250	0.9323	1.0000	1.0000

For a given project, metro locations require 1.66 times as many hours for the ADM function compared to urban, while rural locations require 0.64 times. These figures may be attributable to more layers of management in larger metro districts and the need for consultant management staff. For a given project, rural locations have 1.28 times as many hours in AP compared to urban and metro. This situation may be attributable to the need for a minimum number of staff to cover AP in rural districts. For PSP and PSS, the core PS&E functions, there is no difference in hours required for a project due to location.

When these function-level models were run for a set of projects, it was found that the aggregate was very different from the model for Total PE hours due to the higher errors in the disaggregate models. Ultimately, it was deemed that the Total PE hours model was better, so the decision was made to use a summary estimator at the function level instead of a model. The FY 08–10 data was summarized for each district at the function code level and aggregated to the above staff functions. Figure 2.18 is a bar chart display showing the percentage of each district's PE hours in FY 08–10 that were charged to each staff function. The average came out to be 58%

in PSP, 18% in AP, 17% in PSS, and 7% in ADM. ADM includes Consultant Management and Toll/CDA activities.

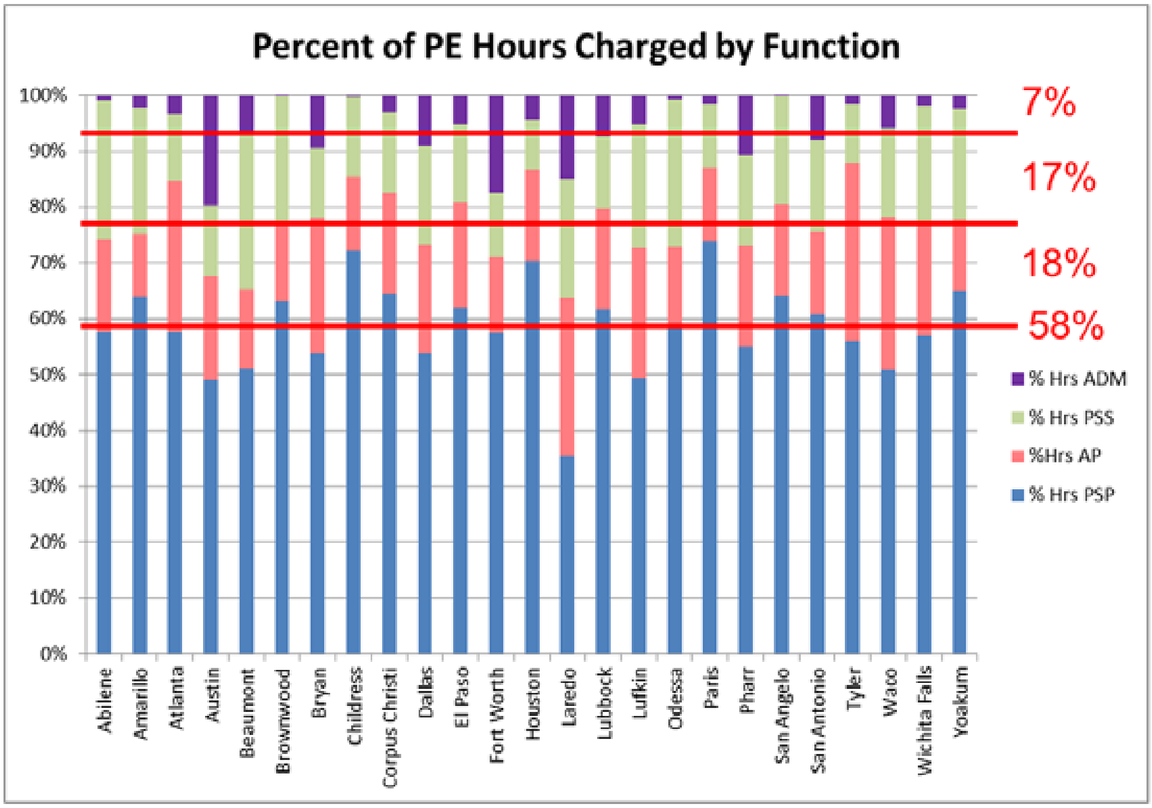


Figure 2.19: Percent of PE Hours Charged by each District to Major PE Functions in FY 08–10

In addition, the number of annual hours per FTE typically charged by each staff function was computed. Table 2.16 shows the results along with the above percentages. The multipliers for Metro and Rural ADM and AP are rounded. These numbers form the basis for converting an estimate of total PE hours into numbers of staff in each function.

Table 2.16: Guides for Estimating PE Function Staff

Function	% of Total Hours		Metro	Rural
ADM	7	250	1.65	0.65
AP	18	1250	1.00	1.25
PSP	58	1300	1.00	1.00
PSS	17	1350	1.00	1.00

For example, say that for a given set of projects in a district's 4-year plan, total district PE hours is calculated by the Total PE Hours model to be 30,000/year. The percentages for AP, PSP, PSS, and ADM are applied and the number of hours for each function is estimated as in Table 2.17. Depending on whether it is a mostly metro, urban, or rural district, the adjustments from Table 2.16 are applied to the estimated PE hours for the relevant functions.

Table 2.17: Example of District PE Function Staff Estimation

Function	% of Total Hrs	Estimated PE Hrs	Adjusted PE Hrs for Rural	PS&E Hrs/FTE/Year	Estimated Staff
ADM	7 %	2100	1365	250	5.5
AP	18 %	5400	6750	1250	5.5
PSP	58 %	17400	17400	1300	23.5
PSS	17 %	5100	5100	1350	4
All	**100%**	**30000**	**30615**		**39**

In the example, a rural district is assumed, and adjustments to ADM (0.65) and AP (1.25) are applied. The adjusted PE hours are then divided by the benchmark PS&E Hours per FTE per year to estimate the staff for each function. The numbers may be rounded up depending on how large they are. In this example, the staff for ADM and AP are each about 5.5. Perhaps this district can have a person with admin and advance planning functions to straddle the 0.5 FTE in each function. The total estimated PE staff for this district is 39.

2.3.4 Effect of Project Durations on PE Staffing

It was noted in FY 11 that staffing demand is dependent on the duration of projects, so even though a district may have enough staff on average, it may not be able to handle peaks in workload. For example, the draft Four-Year Plan from 2010 (see Figure 2.6) was used to compute PE Hours and staffing demand using fixed project durations. Figure 2.19 shows the statewide demand and Dallas district demand for a fixed 12-month duration.

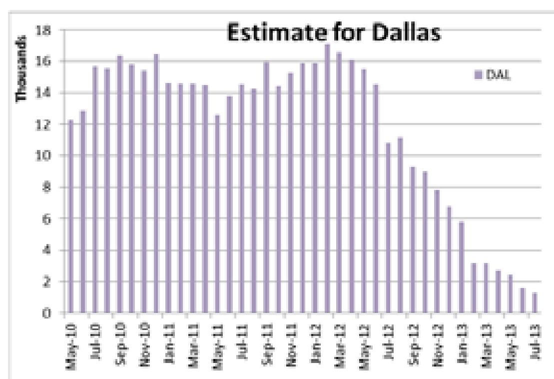


Figure 2.20: PE Hours for Initial 4 Year Plan—Estimate using 12-month PE duration

The profile is very similar to the PE Cost profile in Figure 2.6 earlier. The peak in the period November 2011–May 2012 is about 80,000 hours/month. If we assume 1225 FTE Hour per year (=102 hours/month), that peak demand is about 800 FTEs total. The Dallas district demand is about 16,000 hours/month, or about 160 FTEs (20% of the statewide total). However, those numbers change if the project durations are different.

Figure 2.20 shows the statewide demand and Dallas district demand for a fixed 18-month duration. The peaks have flattened out somewhat. Now the demand in the November 2011; May 2012 period is about 75,000 hours/month, or about 750 FTEs total. The Dallas demand is about 14,000 hours/month, or about 140 FTEs (18% of the statewide total).

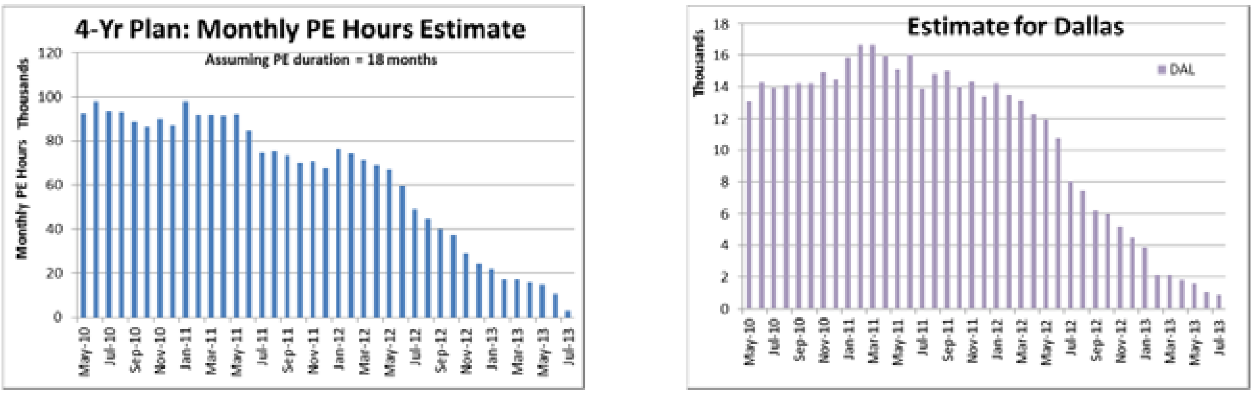


Figure 2.21: PE Hours for Initial 4 Year Plan—Estimate using 18-month PE duration

Figure 2.21 shows the statewide demand and Dallas district demand for a fixed 9-month duration. Now the peaks and valleys are more pronounced. The demand in the November 2011–May 2012 period peaks at over 90,000 hours/month, or about 900 FTEs total. The Dallas demand is about 16,000 hours/month, or about 160 FTEs (18% of the statewide total).

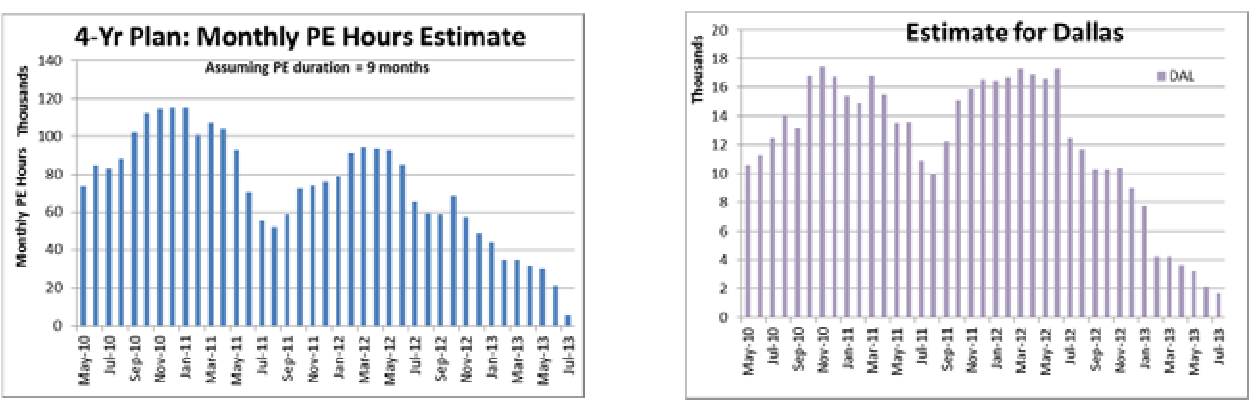


Figure 2.22: PE Hours for Initial 4 Year Plan—Estimate using 9-month PE duration

What these figures illustrate is that PE staffing demand is affected by project durations. Longer durations result in less fluctuation and lower peak demand, while shorter projects create more fluctuation and higher peaks. Larger districts and longer projects foster a more stable staffing situation, whereas smaller districts and shorter projects create instability. Good project duration data is critical to staffing demand estimation.

2.3.5 Duration Data From P6

In an attempt to improve staffing estimation, the research team acquired project duration data from TxDOT's P6 database. This database records district project schedules. Data was acquired on a total of 2146 CSJs with Ready to Let (RTL) dates, i.e., the districts have a firm estimate of when the project will be completed (=3 months before let date). Actual project start dates are also recorded, so estimated PE duration can be computed. Some CSJs have missing dates, and in such cases, the CCSJ dates were used, i.e., it was assumed that the CSJ started and ended on the same dates as the CCSJ. This is a safe assumption, as the CSJ hours will be spread over CCSJ duration. Other data acquired included project type/class, and final estimate of CSJ construction cost.

A model similar to the PE Hours model was developed, correlating CSJ span duration with project construction cost, for each project type. The result is shown in Figure 2.22. The fitted lines are for urban and rural locations. It was found that metro locations have durations 1.45 times those of urban and rural projects.

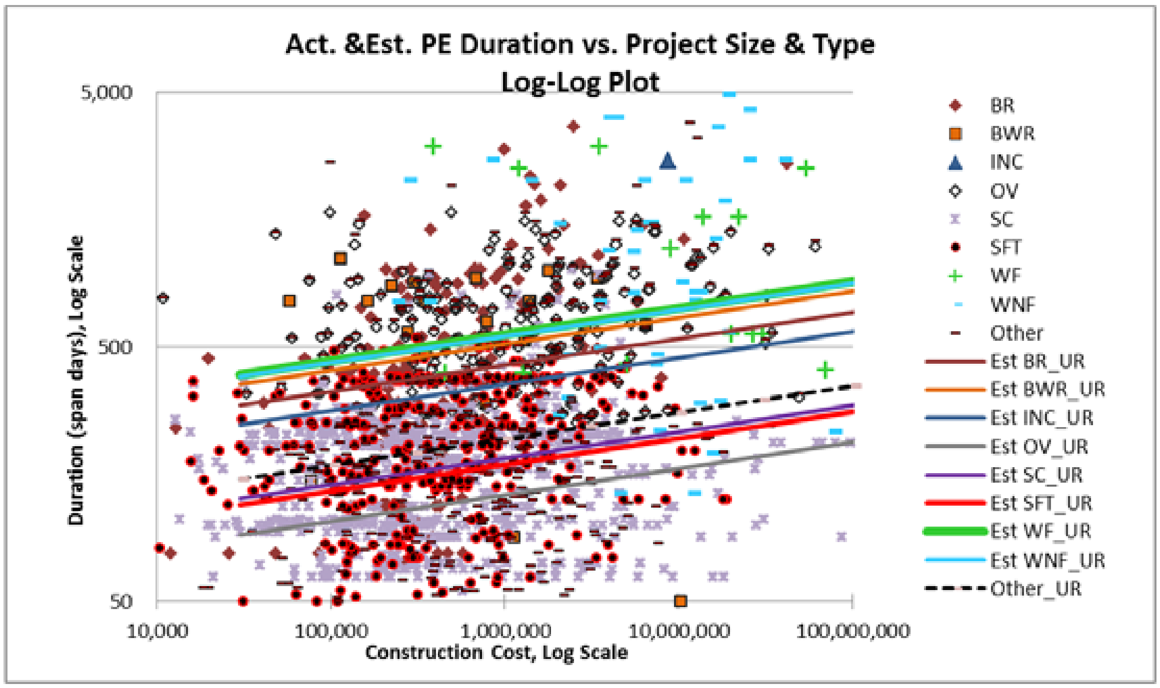


Figure 2.23: Fitted Lines: Duration vs. Construction Cost by Project Type, Log-Log plot

Following are the findings from this quick analysis of the P6 data:

- In general, there is a lot of scatter in the data.
- BR projects have very high durations— one has over 4000 days.
- NLF, NNF and WF projects have very low durations—perhaps only the PS&E phase is being captured, not the advance planning phase.
- TS projects have unexpectedly high numbers.

- P6 data may not be reliable until there is a large and accurate archive of completed projects.

2.3.6 Application of PE Hours Model to 2012 Draft 4 Year Plan

In late 2011, the TxDOT 4-Year Work Plan Task Force provided the research team with a new draft 4-Year Plan, a list of 5537 projects with total construction cost of about $45 billion. The individual monthly total lettings (left axis) and cumulative total (right axis) are shown in Figure 2.23.

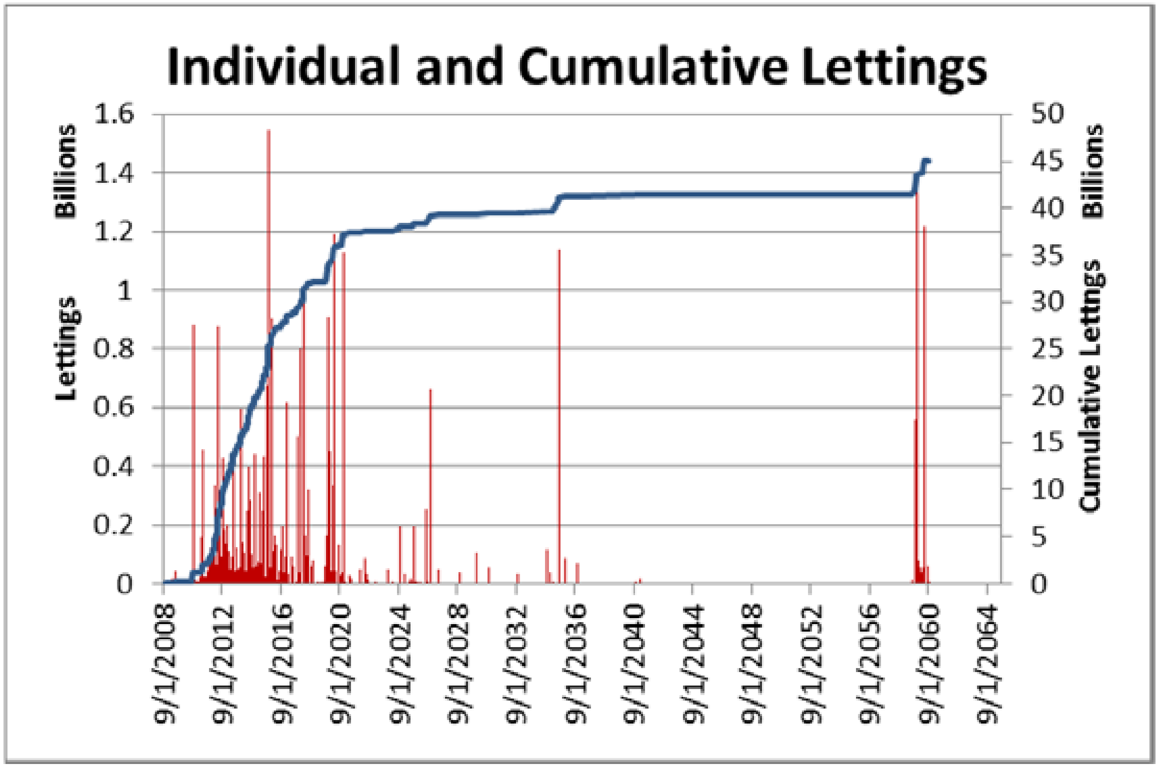


Figure 2.24: Monthly and Cumulative Lettings in 2012 Draft 4 Year Plan

The plan contains lettings from October 2008 to August 2060, with a regular accumulation through 2020 and sporadic amounts thereafter. The outer lettings can be ignored for PE staff planning. Figure 2.24 shows the same profile through 2020.

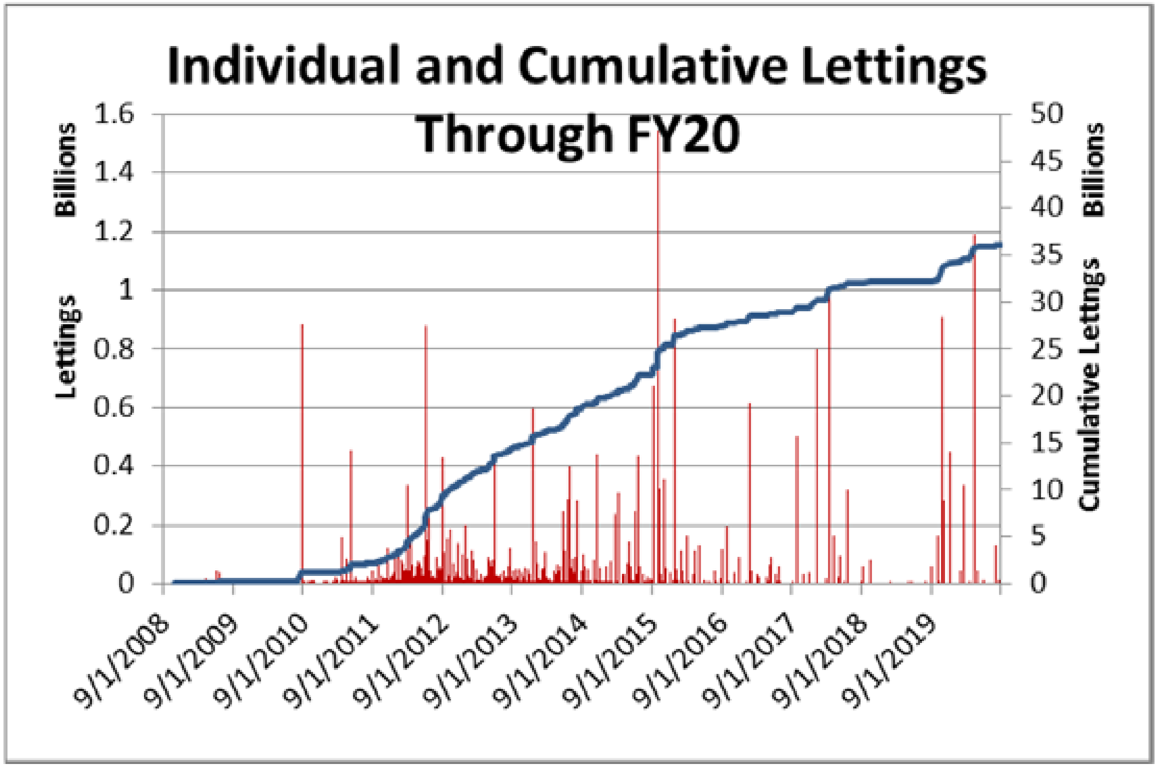


Figure 2.25: Monthly and Cumulative Lettings in 2012 Draft 4 Year Plan Through 2020

Over $35 billion is scheduled by FY 20, with $22 billion by FY 15. These are projects that are of interest in estimating current staffing demand. The draft 4-Year Plan list also contained estimated project construction cost, project type, remaining duration, "Ready to Let" (RTL) dates, and "Revised PSE End Dates." This was sufficient data to apply the PE Hours model and estimate the staffing demand associated with the work plan.

For each project, the total PE Hours required was estimated using the model. The next step was to spread the hours over the PE duration. There was some doubt as to the letting dates for some of the projects, so two alternatives were applied, generating two alternative demand profiles.

Figure 2.25 shows the monthly demand for PE hours using the letting dates given by the districts and research team's estimate of remaining hours on projects already in progress. Figure 2.26 shows the demand using the research team's estimate of letting dates and remaining hours. In the latter case the RTL date was calculated as (12/1/11 + Remaining Duration) if the RTL date appeared over-optimistic.

Depending on what Letting Dates are used, the PE hour demand profile will change. The only significant difference between the alternatives shown in Figures 2.25 and 2.26 is that the peak between January and August 2012 changes. Otherwise, the profiles show staff demand dropping below 100,000 hours per month (~1000 FTEs) by the end of FY 13.

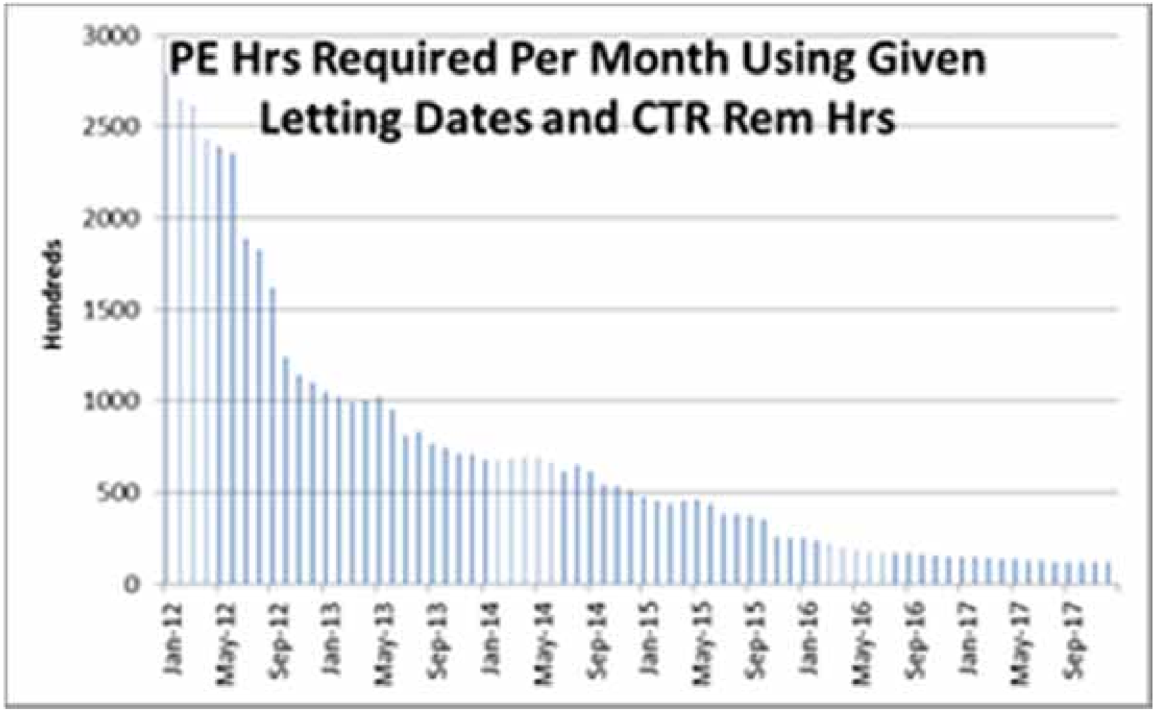


Figure 2.26: PE Hours Demand Profile for 2012 Draft 4 Year Plan-Given Letting Dates

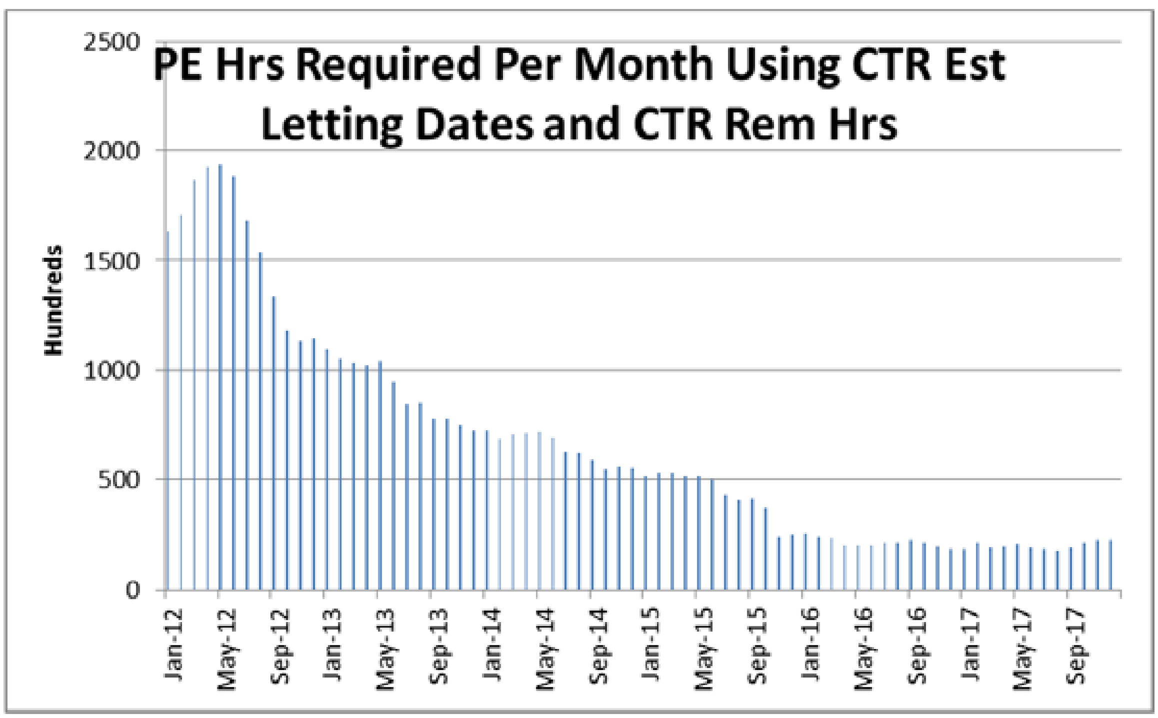


Figure 2.27: PE Hours Demand Profile for 2012 Draft 4 Year Plan-Estimated Letting Dates

2.3.7 Conclusion

The results of applying the PE Hours model to the draft 4-Year plan show that

- The PE Hours model can be applied to any program of work to compute PE Hours and required staffing.
- The letting dates used have an effect on the demand profile, but this effect diminishes in outer years.

The PE Hours model was provided to TxDOT in spreadsheet form. After selecting a specific project type, the user could enter the estimated construction cost and get an estimate of the PE hours required. Details are provided in Chapter 4.

2.4 Task 12C. Construction Staffing

In FY 12, CTR developed CE staffing models. The main subtasks accomplished were to

- Develop a model for estimating CE needs for overall program dollars and funding category dollars.
- Refine models for estimating CE needs and apply to TxDOT's PDP 2012 list of projects when the initial list becomes available from TxDOT.
- Compare the staffing needs predicted with the CST model and provide a summary of results. Hold a workshop with Ken Barnett's group to review similarities and differences and aid in improving the CST model.
- Meet with FIN to ensure that factors for non-work time are captured, and adjust models accordingly to account for inefficiencies.
- Refine the support staff needs model. Meet with Ken Barnett's group to present findings and recommendations on support staff models. Ensure ADM staff is not double counted between the construction staffing and design staffing models.
- Use the model to estimate construction staffing needs when the Prop 12 V2 list of projects is finalized and approved by the commission on the entire portfolio of projects. Expected in October or November 2012.
- Make any adjustments to CE staffing estimates as needed during FY12 based on feedback from TxDOT. Submit final models by June 30, 2012.
- Upon the PD's request, conduct a survey of comparable DOTs to identify the methodology used by them for determining construction staffing during times of 'uncertain' funding. Identify best practices and methods used for determining staffing levels and report findings to the panel.

2.4.1 CE Curves

The purpose of this effort was to investigate the construction engineering costs associated with TxDOT's portfolio of construction projects and convert those costs to forecast staffing needs for managing construction contracts during the construction phase. In order to accomplish this, a relationship between project characteristics and CE costs was developed through a stepwise multivariate regression analysis using the statistical software package SPSS® 19.0.

The CE costs from TxDOT construction projects closed in FY 10 were used to develop the statistical model for construction engineering (CE) costs. Data consisting of costs associated with function codes (FC) 310-390 for a total of 11,186 CSJ projects were obtained from TxDOT's Financial Information Management System (FIMS). Construction costs and project type information were obtained from TxDOT as well. CE costs were calculated by summing up management costs (F310), inspection costs (F320), and laboratory costs (F330). A total of 8,822 projects that had currently active (status 1 and 2) or zero values of cost information had to be excluded, leaving 2,364 closed projects (status 3 and 4). To create a CCSJ CE model, CSJ projects under the same CCSJ contract were combined by adding up the respective construction and CE costs of all the CSJ projects within the CCSJ. As a result, a total of 1,016 CCSJ projects including 25 different project types were used in the analysis. The statistics of CCSJs used are summarized by project type in Table 2.18.

Table 2.18: Summary of Analyzed TxDOT CCSJ Projects by Type

#	Project Type	Project Description	No. of Projects	Construction Costs		CE Costs	
				Mean	Std. Dev.	Mean	Std. Dev.
1	BPS	Bridge Preventive Maintenance-Sealed	2	209,124	188,308	2,298	2,251
2	BR	Bridge Replacement	179	1,660,005	1,949,729	109,671	99,814
3	BWR	Bridge Widening or Rehabilitation	45	2,125,108	3,451,427	135,118	135,516
4	CNF	Convert Non-Freeway to Freeway	7	40,202,837	31,066,514	1,748,399	1,198,498
5	CTM	Corridor Traffic Management	10	1,512,340	887,243	89,293	64,404
6	HES	Hazard Elimination and Safety	3	756,594	559,219	41,783	33,417
7	INC	Interchange New or Reconstructed	15	47,606,424	72,433,280	1,869,664	2,653,642
8	LSE	Landscape and Scenic Enhancement	14	581,604	443,523	80,084	65,810
9	MSC	Miscellaneous Construction	178	2,171,937	7,436,786	116,462	394,208
10	NLF	New Location Freeway	1	62,946,893	-	1,416,627	-
11	NNF	New Location Non-Freeway	13	12,413,793	14,659,348	467,996	472,212
12	OV	Overlay	122	3,128,467	4,178,432	100,599	139,929
13	RER	Rehabilitation of Existing Road	131	5,032,378	8,422,370	219,522	263,318
14	RES	Restoration	38	3,349,994	2,211,878	148,203	126,226
15	SC	Seal Coat	42	2,523,133	3,579,770	72,169	176,056
16	SFT	Safety	100	2,439,439	3,130,454	108,582	96,147
17	SKP	SKIP (Exempt from sealing) - Enhancement Project	9	1,898,685	2,705,143	37,417	25,120
18	SRA	Safety Rest Area	3	9,544,289	9,652,137	250,069	199,753
19	TPD	Traffic Protection Devices	3	2,564,661	2,961,185	126,211	38,930
20	TS	Traffic Signal	30	821,199	622,031	79,725	60,886
21	UGN	Upgrade to Standards Non-Freeway	10	3,037,172	2,525,580	150,204	110,620
22	UPG	Upgrade to Standards Freeway	6	10,496,262	11,598,088	341,891	220,049
23	UTL	Utility Adjustments	1	793,734	-	29,578	-
24	WF	Widen Freeway	13	31,158,427	21,431,740	1,265,436	641,830
25	WNF	Widen Non-Freeway	41	14,334,573	9,993,106	592,889	345,667

Prior to the analysis, several assumptions were examined to justify the use of linear regression models, including (1) linearity, (2) independence, (3) homoscedasticity, and (4) normality. To test conformity with linearity, an initial linear regression of CE costs to construction cost was performed, finding that there was an R^2 of 0.925. The residuals are plotted as shown in Figure 2.28.

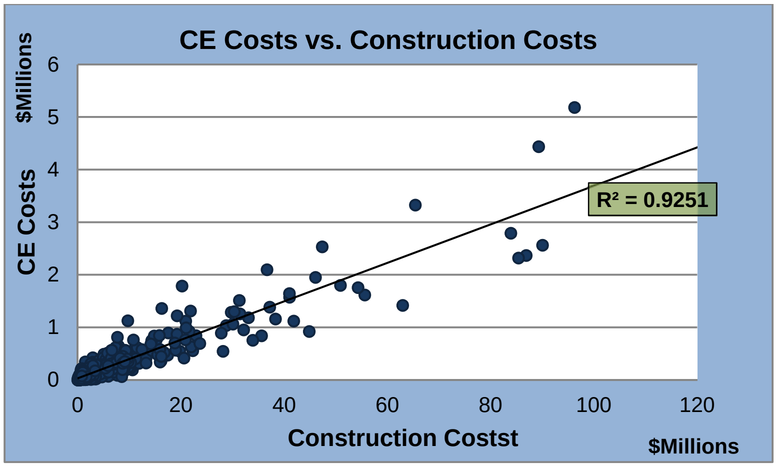


Figure 2.28: Scatter Plots of CE Costs vs. Construction Costs (Before Transformation)

According to the scatter plots, however, the distributions of independent and dependent variables seemed to be substantially skewed, which violated the assumption of a normal distribution. This violation of normality can frequently increase the likelihood of either a Type I or II error. Therefore, transformation of these variables is essential for normal distribution of residuals. To spread the data points more uniformly, CE costs and construction costs data was transformed using the logarithm function. This log transformation is commonly used for positive and non-zero data. As a result of log transformation, the residuals are normally distributed by indicating that the skewness is in the range of -1 to 1 and kurtosis is between 2 and -2. Figure 2.29 shows the scatter plots after transformation.

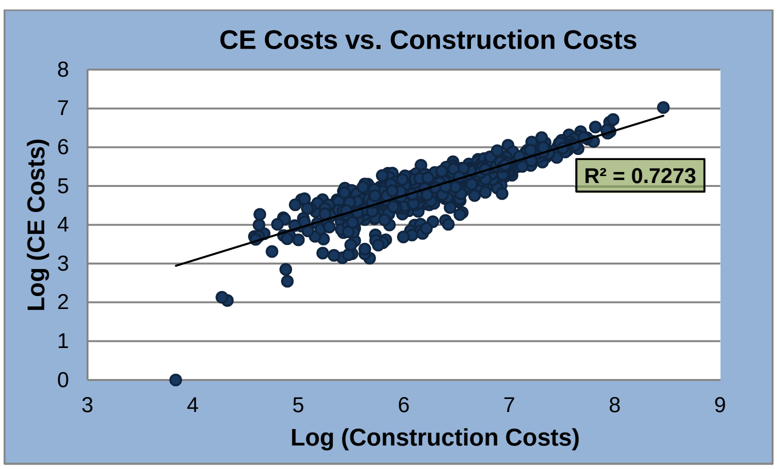


Figure 2.29: Scatter Plots of CE Costs vs. Construction Costs (After Transformation)

The proposed CE cost model is a log-linear relationship of the form (Equation 2.1):

$$\log(y_{\text{CEcosts}}) = \beta_0 + \beta_1 \times \log(x_{\text{constr cost}}) + \beta_2 \times x_{\text{proj type}} + \beta_3 \times x_{\text{proj type}} \quad \text{(Eq. 2.1)}$$

To examine the relationship, a stepwise multivariate regression analysis was conducted using the statistical software package SPSS® 19.0. This stepwise regression analysis iteratively tests the independent variables and automatically adds to or removes from the model based on the F-test. This method is able to find the best combination of provided independent variables to estimate the dependent variable. This regression model represents the relationship between the dependent and the independent variables and also yields analysis of variance (ANOVA). The final model contains a continuous variable of construction costs, and categorical variables of project types (Project Class). The coefficients of the variables in the final model indicate their relative impacts on the dependent variable.

To compare the impacts of project type and construction cost on CE costs, the regression analysis designated overlay (OV) as the reference project type. The result yields a significant model, $F(20,994) = 224.619$, $p<0.001$, Adjusted R square = 0.815. Table 2.19 summarizes the significant variables in the model. It is found that project construction cost and project type account for about 81.5% of the variance in CE costs.

Table 2.19: Regression Model for CE Costs with Different Project Types

Variables	Coefficients (B)	Std. Error	P-value
(Constant)	-0.203	0.103	0.049
Log(ConstrCosts)	0.799	0.016	0.000
SC	-0.413	0.043	0.000
BR	0.291	0.028	0.000
BPS	-0.740	0.173	0.000
LSE	0.449	0.069	0.000
BWR	0.324	0.042	0.000
TS	0.350	0.049	0.000
INC	0.348	0.068	0.000
WNF	0.265	0.045	0.000
RER	0.198	0.030	0.000
WF	0.325	0.072	0.000
CNF	0.386	0.095	0.000
SFT	0.183	0.032	0.000
MSC	0.163	0.028	0.000
NNF	0.213	0.071	0.003
UPG	0.255	0.101	0.012
UGN	0.206	0.079	0.009
TPD	0.338	0.141	0.017
RES	0.099	0.044	0.025
CTM	0.162	0.079	0.041

In particular, construction cost has a significantly positive effect on CE costs, with a coefficient of 0.799 for Log (Construction Cost). Thus, CE costs tend to increase as project size increases with a power factor of 0.799, confirming the log-normal distribution. The coefficient of each project type vary from -0.740 to 0.449, with more complex project types such as bridge replacement and traffic signal having higher coefficients, while simpler projects like seal coat have lower coefficients. These coefficients give a model for each project type as shown in Equation 2.2:

$$\text{Log(CE Costs)} = -0.203 + 0.799 \times \text{Log (Construction Costs)} - 0.413 \times SC + 0.291 \times BR - 0.740 \times BPS + 0.449 \times LSE + 0.324 \times BWR + 0.350 \times TS + 0.348 \times INC + 0.265 \times WNF + 0.198 \times RER + 0.325 \times WF + 0.386 \times CNF + 0.183 \times SFT + 0.163 \times MSC + 0.213 \times NNF + 0.255 \times UPG + 0.206 \times UGN + 0.338 \times TPD + 0.099 \times RES + 0.162 \times CTM \quad \text{(Eq. 2.2)}$$

The fitted lines estimated by the model are shown in Figure 2.30. The labeled lines are for the project types as listed earlier. In particular, project types that were not included in the model were grouped as "Others." Each line is plotted only for the observed range of project construction cost for that project type. Figure 2.31 shows the data zoomed in to the $ 30 million construction cost range because some of the projects (i.e., BPS, and TS) are comparatively smaller in construction cost. The graphs indicate that, as project construction cost increase, CE costs also increase, but at different rates for different project types. For example, CE costs for CNF and WF projects rise faster than those for overlay projects (the reference project). On the other hand, CE costs for seal coat projects are lower than the reference project. Figures 2.32–34 give a better sense of the difference in CE costs for different project types.

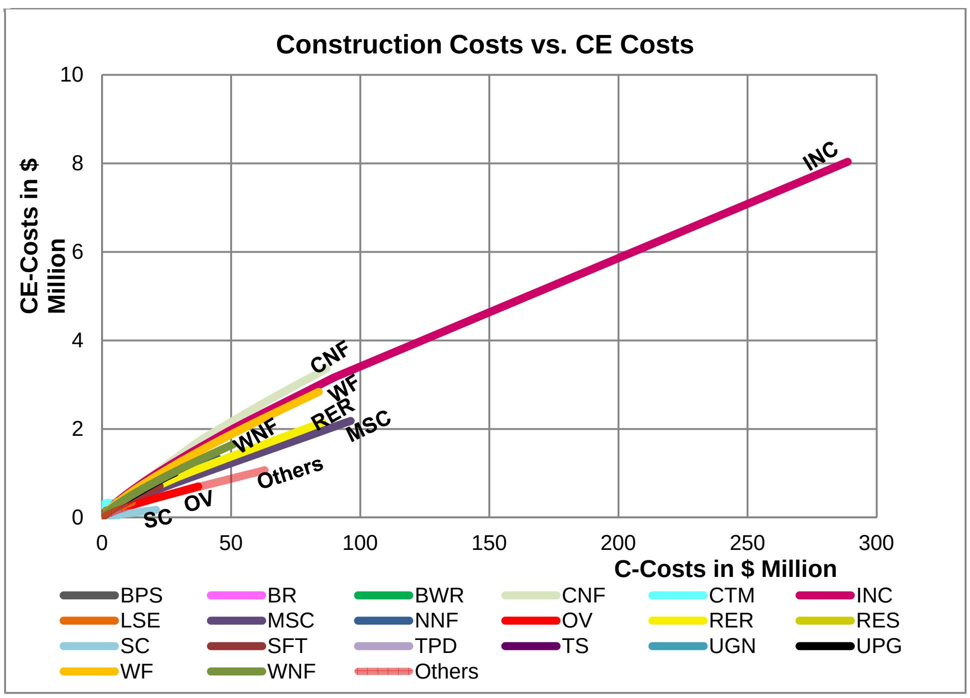


Figure 2.30: Graphs for Construction Costs vs. CE Costs by Project Type

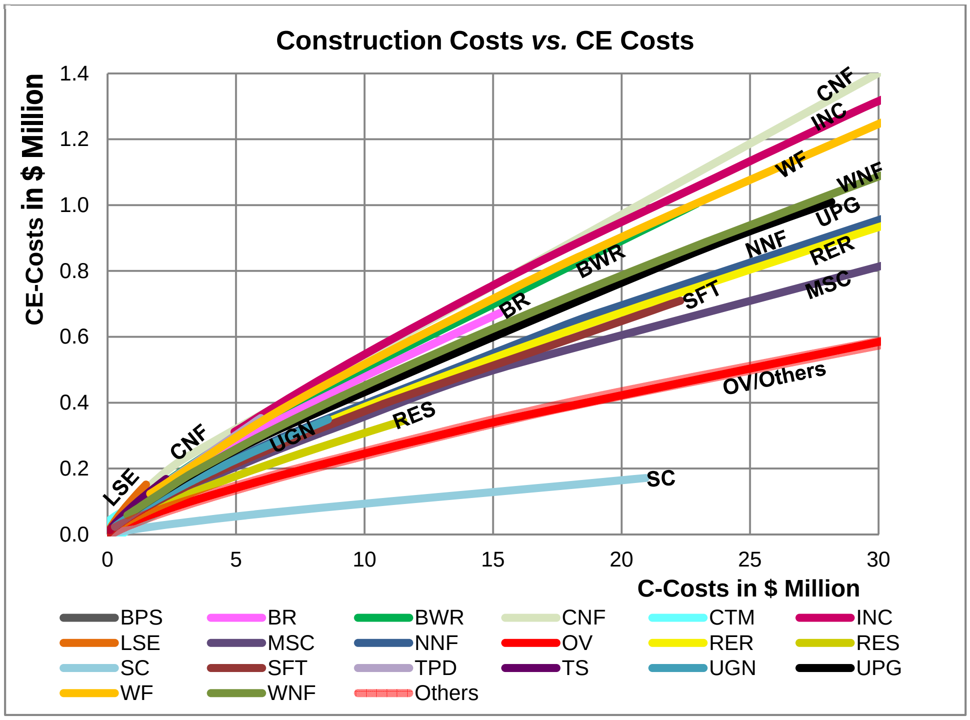


Figure 2.31: Graphs for Construction Costs vs. CE Costs by Project Type (Zoomed)

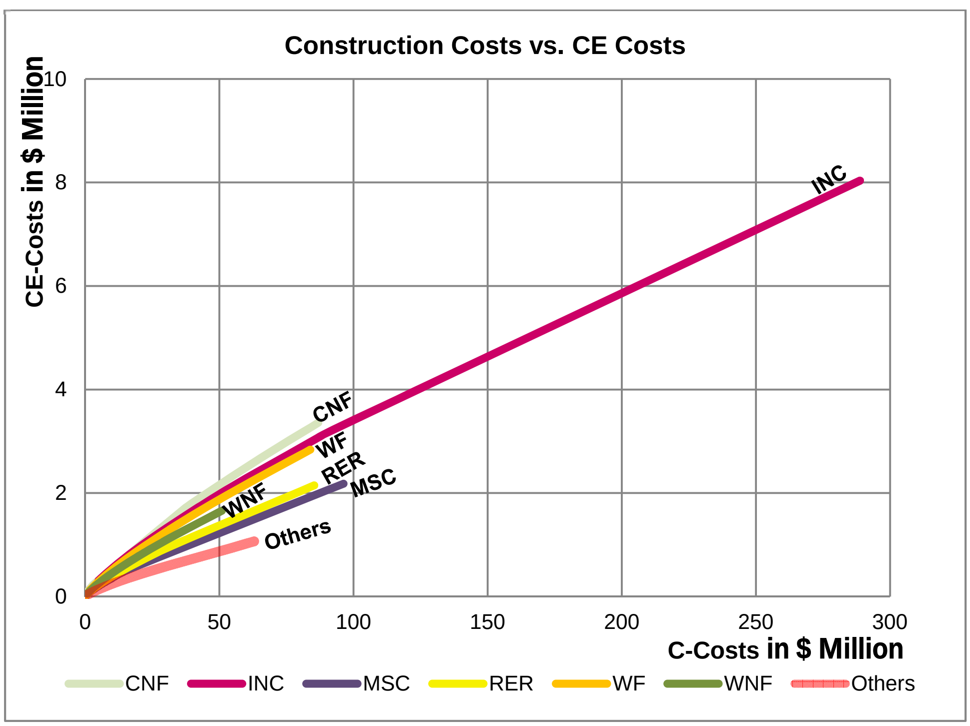


Figure 2.32: Graphs for CNF, INC, WF, WNF, RER, MSC, and Others

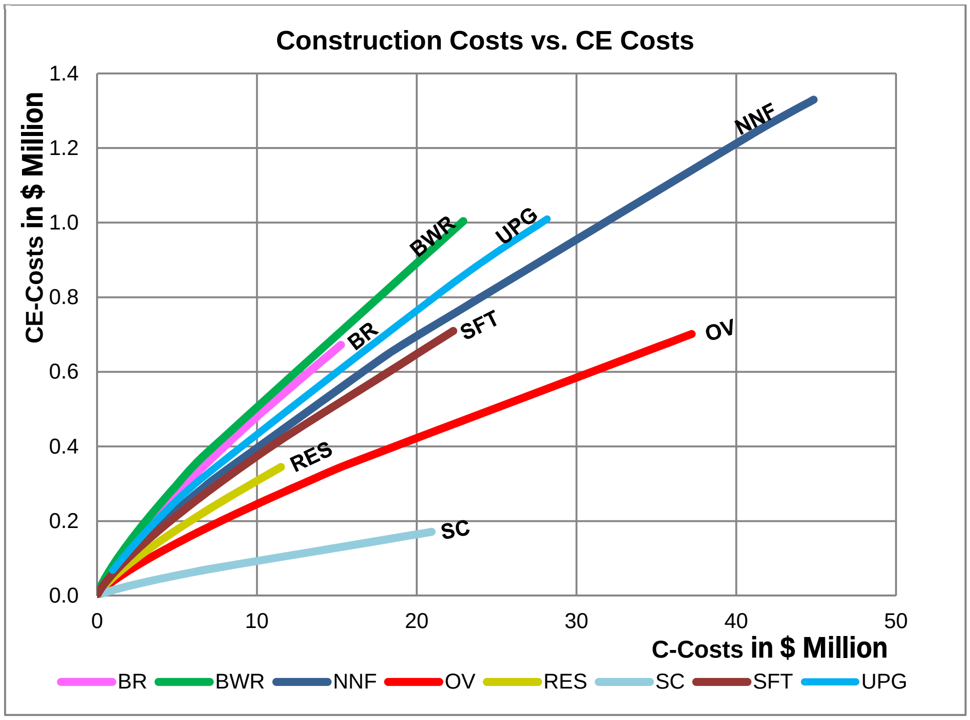


Figure 2.33: Graphs for BWR, BR, UPG, NNF, SFT, RES, OV, and SC

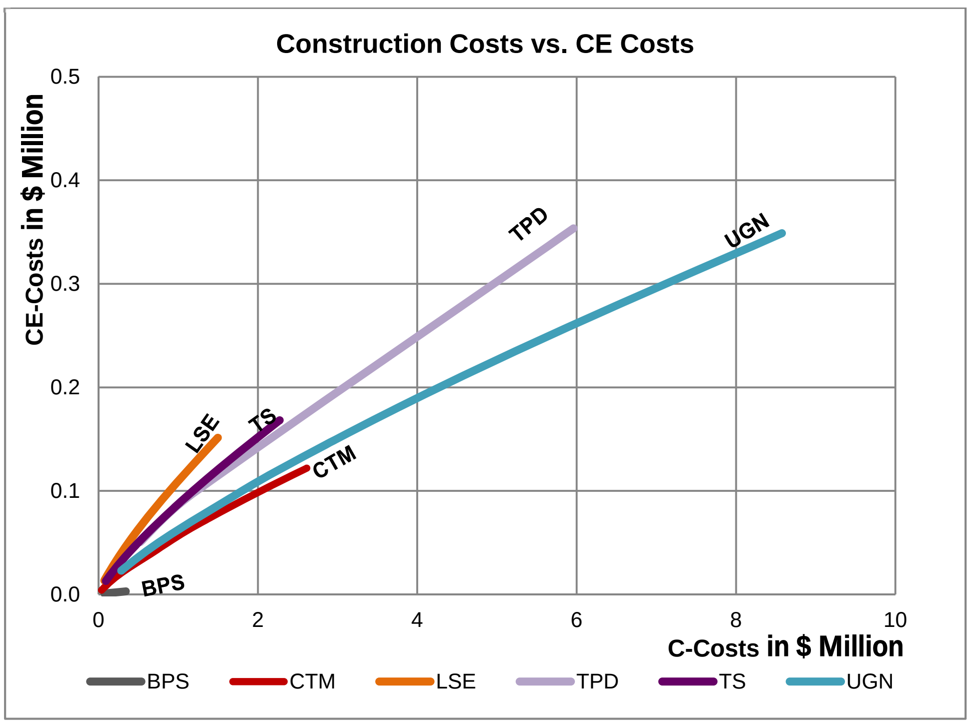


Figure 2.34: Graphs for LSE, TS, TPD, UGN, CTM, and BPS

2.4.2 CE Costs

Percentage CE costs were computed using the following formula (Equation 2.3).

% CE Costs = Estimated CE Costs/Construction Costs	(Eq. 2.3)

As with CE costs, these percentages vary depending on construction cost and project type. For the full dataset, CE costs are estimated at approximately 5.6% of the total construction costs. In general, the % CE costs decrease as construction costs increase. Figure 2.35 shows the difference in percent CE costs by different project type.

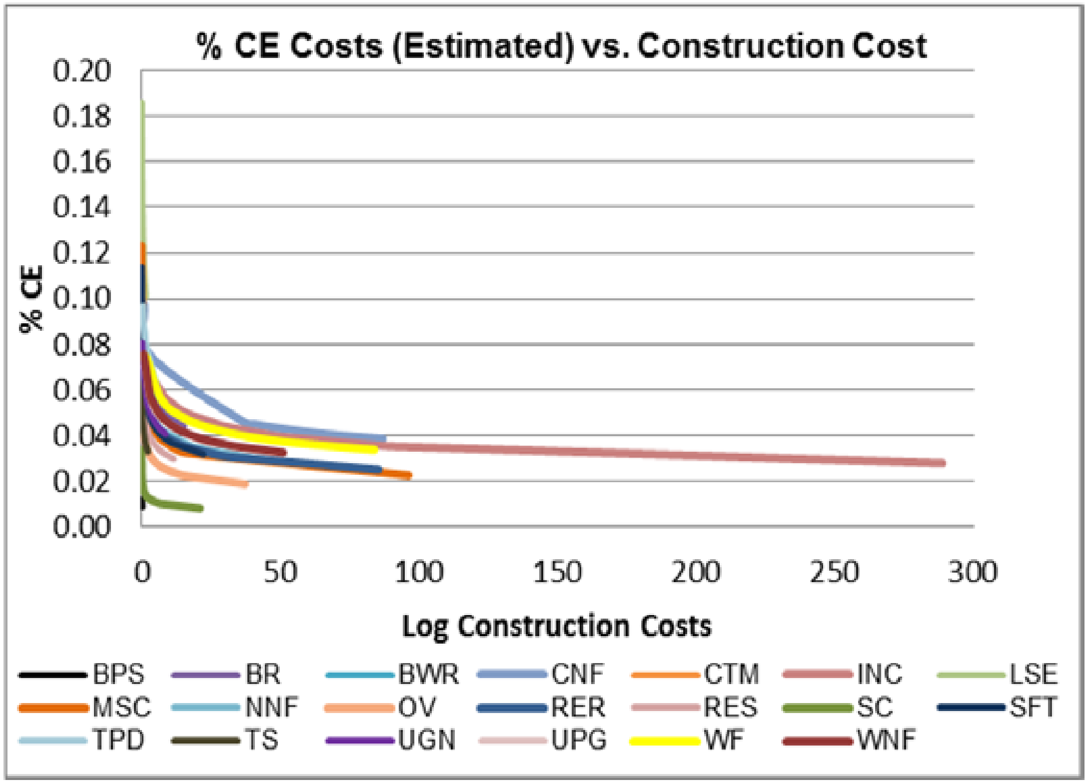


Figure 2.35: Percent CE Costs (Estimated) vs. Construction Cost (All Project Type)

The % CE cost of each project type varies from 0.008 to 0.186. To give a better sense of the numbers, the lines are shown in the following Figures 3.9–11 on a zoomed scale. Added capacity projects such as bridge widening (BWR), interchange (INC), and freeway upgrading (UPG) have higher % CE costs, while pavement projects like overlay (OV) and seal coat (SC) have lower % CE costs.

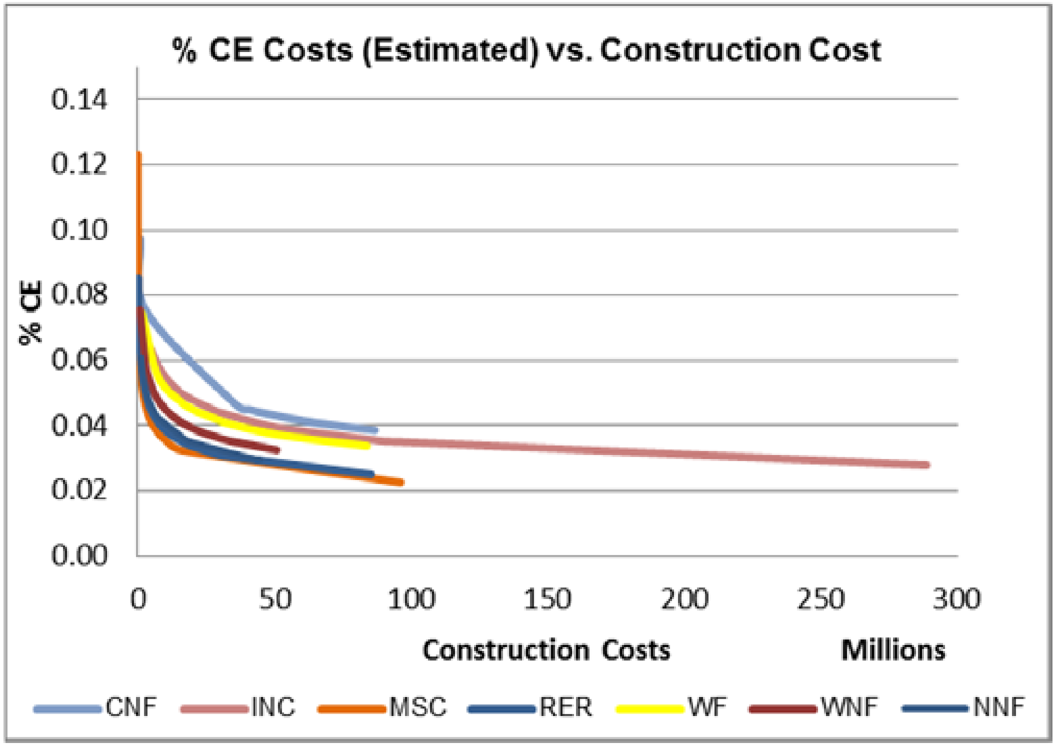


Figure 2.36: Percent CE Costs vs. Construction Cost (CNF, INC, MSC, RER, WF, WNF, and NNF)

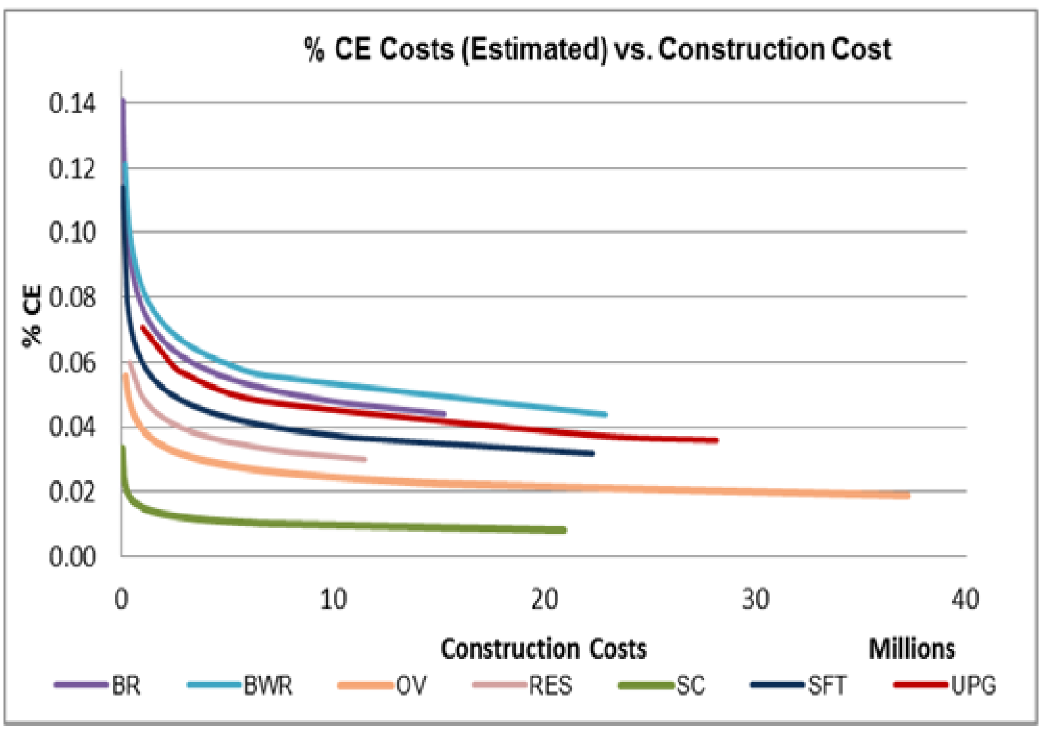


Figure 2.37: Percent CE Costs vs. Construction Cost (BR, BWR, OV, RES, SC, SFT, and UPG)

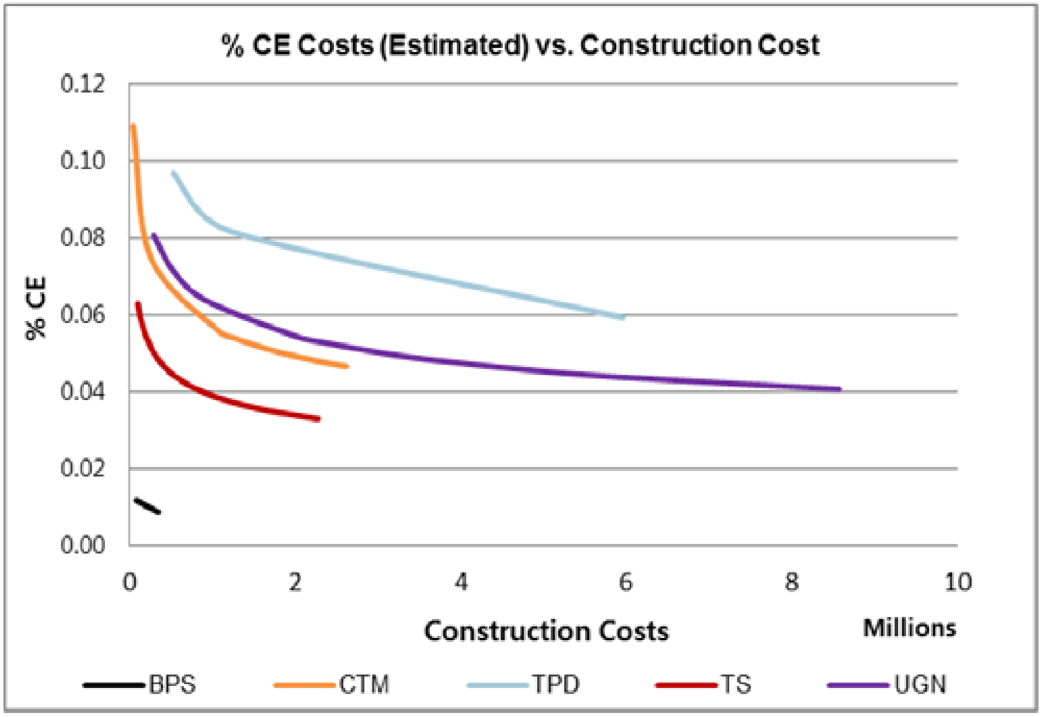


Figure 2.38: Percent CE Costs vs. Construction Cost (BPS, CTM, TPD, TS, and UGN)

2.4.3 CE Costs and Construction Staffing Needs

The TxDOT Construction Engineering Costs (FIMS Segment 76-FC 3xx) can be summarized into four categories, consisting of

- salaries (of TxDOT staff charging directly to construction projects),
- indirect costs (overhead costs distributed across projects),
- services (provided by non-TxDOT entities), and
- others (consists of everything else, including but not limited to, materials, supplies, equipment, etc.).

About 53% of the CE expenditure was for salaries, 33% for indirect costs, and 7% for services. The remaining 7% of the CE expenditure was for others. Figure 2.39 presents distribution of CE costs by category.

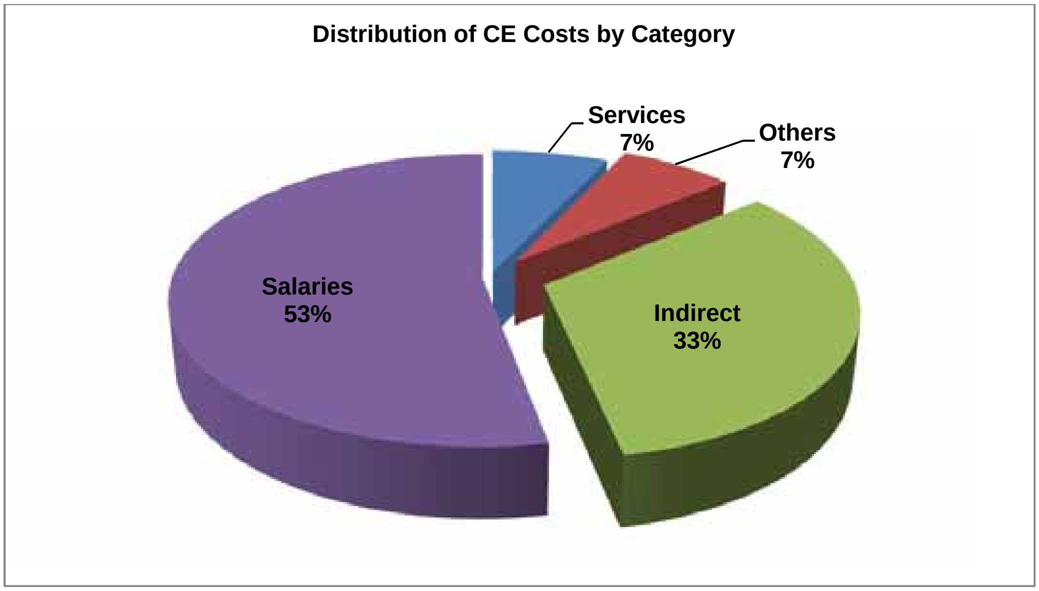


Figure 2.39: Distribution of CE Costs by Category

Figure 2.40 shows TxDOT construction engineering costs by fiscal year. Between FY 08 and FY10, the total CE costs were decreasing from $219.0 million to $168.7 million, while the percentage used for salaries was increasing from 50.2% to 54.5%.

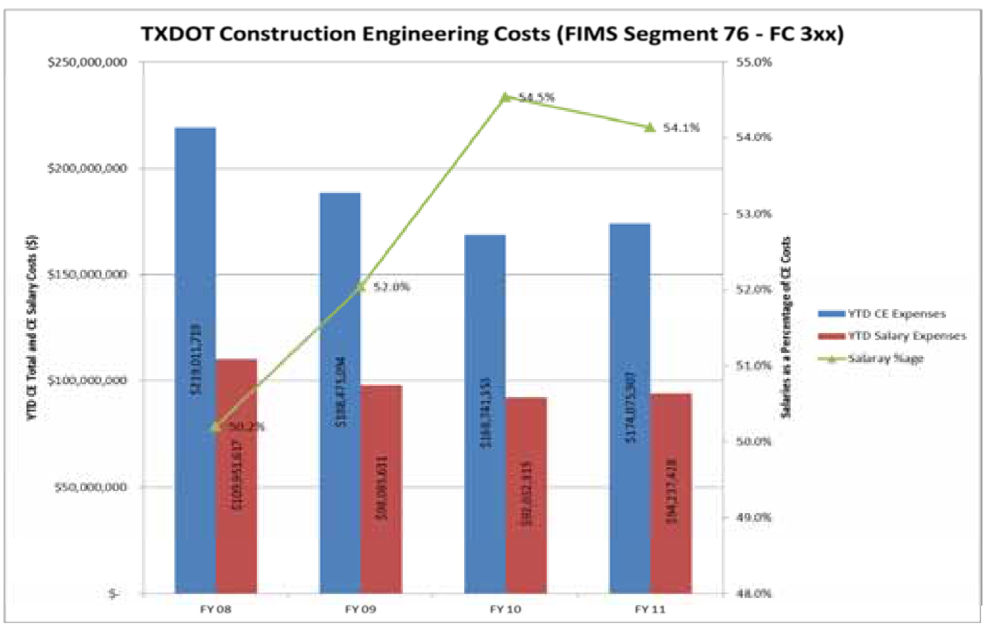


Figure 2.40: TxDOT Construction Engineering Costs (FIMS Segment 76-FC 3xx)

To investigate the average salaries of construction staff charging to FIMS segment 76 FC 3xx, TxDOT HRD compiled a dataset from a survey of 25 Districts in response to a CTR request. As a result, the average salaries of the construction inspection staff were computed at

$4,986.19 per month or $28.77 per hour. Figure 2.41 shows the example of the survey questionnaire for average salaries of construction staff.

Average Salaries of Construction Staff
Charging to FIMS Segment 78 FC 3xx

	Inspectors		Record Keepers		Lab Staff		Construction Auditors		Gen Eng Techs (Charging to FC 3xx)		Total	
D/O/O	# Empl	Avg Monthly Salary	# Empl	Avg Monthly Salary	# Empl	Avg Monthly Salary	# Empl	Avg Monthly Salary	# Empl	Avg Monthly Salary	# Empl	Avg Monthly Salary
ABL												
AMA												
ATL												
AUS												
BMT												
BWD												
BRY												
CHS												
CRP												
DAL												
ELP												
FTW												
HOU												
LRD												
LBB												
LFK												
ODA												
PAR												
PHR												
SJT												
SAT												
TYL												
WAC												
WFS												
YKM												
BRG												
MNT												
CST												
TxDOT Total												

Figure 2.41: TxDOT Construction Staff Salary Survey Form

2.4.4 Number of Inspectors Calculated by the CTR Model

The CTR construction inspector staffing model estimated inspector needs primarily based on the CE cost model. As discussed, the CE cost estimates vary depending on project type and dollar value of construction work. As a result, the number of inspector needed for a project depends on project type and size. The basic concept of computing inspector needs is dividing CE costs by an average salary. Using the CE model shown in Equation 2.4, CE costs can be estimated from the dollar value of different types of construction work.

$$\begin{aligned}\text{Log(CE Costs)} = {} & -0.203 + 0.799\times\text{Log (Construction Costs)} - 0.413\times SC + 0.291\times BR - 0.740\times BPS + \\ & 0.449\times LSE + 0.324\times BWR + 0.350\times TS + 0.348\times INC + 0.265\times WNF + 0.198\times RER + \\ & 0.325\times WF + 0.386\times CNF + 0.183\times SFT + 0.163\times MSC + 0.213\times NNF + 0.255\times UPG + \\ & 0.206\times UGN + 0.338\times TPD + 0.099\times RES + 0.162\times CTM \qquad \text{(Eq. 2.4)}\end{aligned}$$

Estimated CE costs can be spread evenly over the construction duration. On a single project, inspector needs will follow the classic S-curve of initial low demand followed by peaking and sharp decay. However, over a large number of projects starting at different times and having different S-curves, the aggregate is quite even and can be modeled as the sum of averages. Then, monthly CE costs can be divided by an average monthly salary, which produces the number of inspector needs per month. As a result, the total number of inspector needs can be calculated by summing up all of the monthly inspector needs for construction work in a specific period.

Using the above model, the CST database of Nov. 2010 was analyzed to calculate the number of inspector needs. The total dollar value of construction work for the period January 2011 through June 2014 was approximately $58.7 billion. The model estimated that in January 2010, 2,015 inspectors are needed, continuously decreasing to 1,008 inspectors in June 2014. The results of the inspector needs are shown in below Figure 2.42.

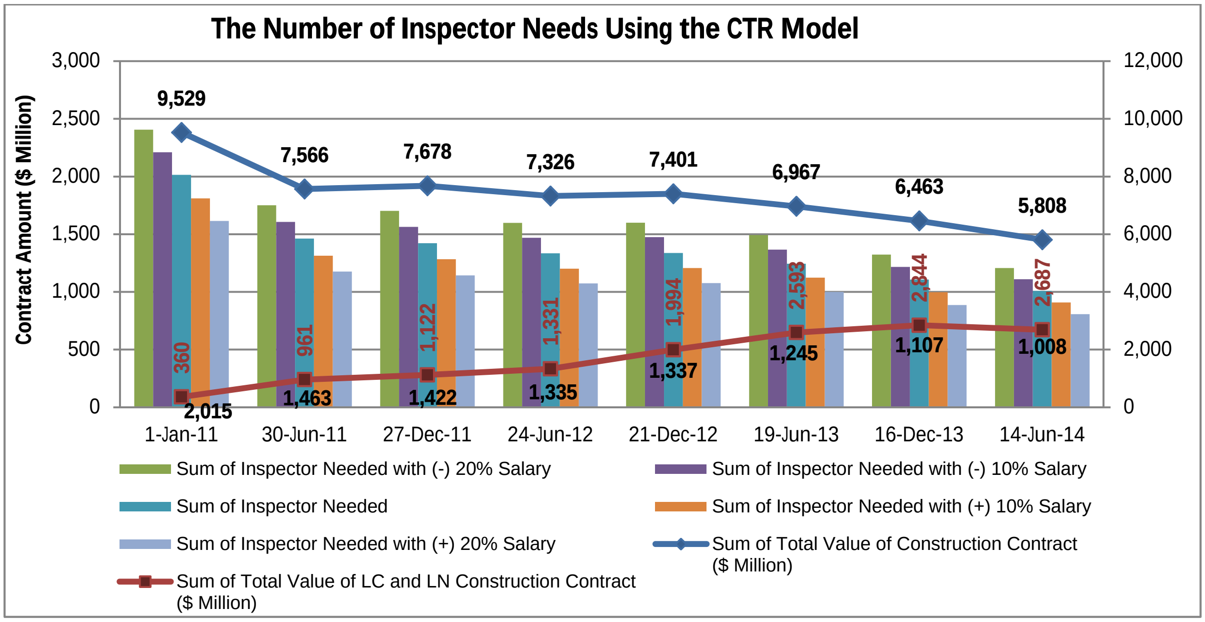


Figure 2.42: CTR Construction Inspector Staffing Model Output

2.4.5 Support Staff

To collect relevant information on the staff required for supporting district construction operations, a survey of district CE practices was conducted. After pilot-testing, the survey questionnaire was distributed to all districts in Texas (n=25). All of the districts responded to the survey. Some of the questions are included below.

1. How many Construction Inspectors, Engineers and EITs' in your District, including all area offices & specialized offices (if applicable) are assigned to **inspection duties on construction projects** (If some of your non-construction staff splits time between construction inspection and other duties, then estimate the construction inspection contribution using the table below, i.e., 6 maintenance technicians spend about 1 month during summer inspecting construction projects then count them as shown in the table below).

Primary Job Function	Total Employees & Percent Time	Full-Time Equivalent
Construction Inspectors FTE		
MNT Staff assigned to P/T construction inspection		
TRF section staff assigned to inspection		
Others (Please specify)		
Project Engineers		

2. How many engineers and non-engineers in your District are currently assigned to the *support function* at the **Area Office level** (include AO Lab personnel as well, if applicable)?

Construction Support Staff at Area Office Level (Include ALL Area Offices	Numbers (FTE)	Primary Function	Average Percentage of Time Charges to Overhead
Area Engineers			
Assistant Area Engineer(s)			
Record Keeper(s) / Auditor(s)			
Area Office Lab Supervisor /Tech(s)			
Others (Please specify)			

3. How many engineers and non-engineer *support staff* are available in your **District Office** to support the **District's** construction office? (Use the Table below)

Construction Support Staff	Numbers (FTE)	Primary Function	Average Percentage of Time Charges to Overhead
Director of Operations			
Construction Manager			
Record Keeper(s) / Auditor(s)			
Other Personnel in District Construction Office			
District Lab Engineer/ Supervisor/Tech(s)			
Others (Please specify)			

The results showed that support staff definition is not consistent across Districts. For example, time charges to overhead functions by Area Engineers and Directors of construction range from 10% to 100%. Construction support staff may wear multiple "hats" in smaller districts. In particular, support staff may charge time directly to CSJ(s) in smaller districts, while it is common for support staff to charge time to overhead in larger districts. The results of the survey are summarized below in Tables 2.20–21.

Table 2.20: Number of FTEs Based on the Survey Results

Number of FTE	Question 1	Question 2	Question 3
0-25	11	22	24
25-50	9	2	1
75	3	1	0
75+	2	0	0
Sum	25	25	25

Table 2.21: Statistics of the Survey Results

	Question 1	Question 2	Question 3
Average	40.2	18.5	12.1
StdDev	39.9	15.9	6.6
Max	182	75	31
Min	8.5	4	6

In general, the number of inspection and support staff increases as the amount of construction contracts increases. In addition, the ratio of inspector and support staff also increases as dollar amounts of construction contracts increase. Figure 2.43 shows the result of the CST support staff model analysis.

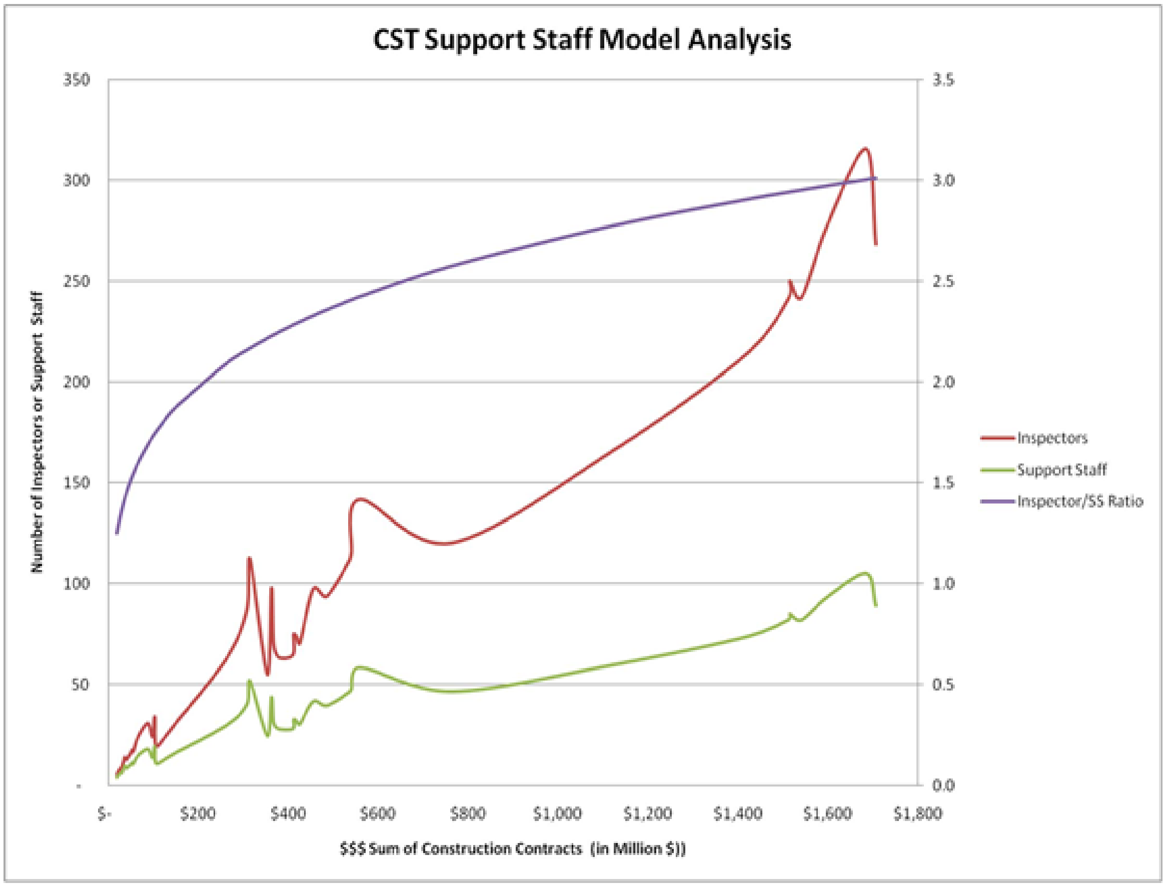


Figure 2.43: CST Support Staff Model Analysis

2.4.6 Duration Model

A model for project construction duration was developed using data from a total of 6928 CSJ projects constructed between 2001 and 2011. The data, which was obtained from TxDOT's Construction Division, included construction costs and duration and project type. In particular, project duration was computed based on the span time in months from first to last payment, including the establishment of the vegetative cover before the final payment is made. Using listwise deletion, the researchers removed 5,330 projects with missing or no values in any of the variables from the sample. As a result, a total of 1,598 projects including 23 different project types were used for the analysis. The statistics of the TxDOT construction projects used are summarized by project type below in Table 2.22.

Table 2.22: Statistics of Construction Projects Studied for Duration Model

No	Project Type	Project Description	No. of Projects	Ave. Const. Costs ($M)	Ave. Duration (Months)
1	BCF	Border Crossing Facility	2	6.49	23.0
2	BR	Bridge Replacement	221	3.23	14.6
3	BWR	Bridge Widening or Rehabilitation	54	3.42	19.0
4	CNF	Convert Non-Freeway to Freeway	17	53.87	40.0
5	HES	Hazard Elimination and Safety	8	0.82	11.6
6	HPR	Hazardous Paint Removal (BR Rehab)	1	1.09	22.0
7	INC	Interchange New or Reconstructed	49	32.41	33.8
8	LSE	Landscape and Scenic Enhancement	52	1.06	19.9
9	MSC	Miscellaneous Construction	336	2.41	16.3
10	NLF	New Location Freeway	10	63.11	35.0
11	NNF	New Location Non-Freeway	45	12.53	22.8
12	OV	Overlay	147	2.48	8.1
13	RER	Rehabilitation of Existing Road	145	7.02	18.9
14	RES	Restoration	20	1.87	11.2
15	SC	Seal Coat	33	4.53	9.7
16	SFT	Safety	216	1.33	10.4
17	SRA	Safety Rest Area	3	7.12	11.0
18	TPD	Traffic Protection Devices	3	0.67	12.3
19	TS	Traffic Signal	42	0.78	19.2
20	UGN	Upgrade to Standards Non-Freeway	11	12.83	31.8
21	UPG	Upgrade to Standards Freeway	14	23.44	28.1
22	WF	Widen Freeway	41	58.39	39.4
23	WNF	Widen Non-Freeway	128	13.32	26.2

In addition, these projects can be categorized by the degree of urbanization. Based on size of their population, 254 counties of Texas are categorized into three different county groups: (1) metro county (population>250,000), (2) urban county (50,000<population≤250,000), and (3) rural county (population<50,000). Urban counties had the highest amount of work, taking about 54% of the total construction costs, with metro and rural counties taking about 17 % and 29% respectively. Figure 2.44 presents the summary of TxDOT construction costs by the degree of host county urbanization.

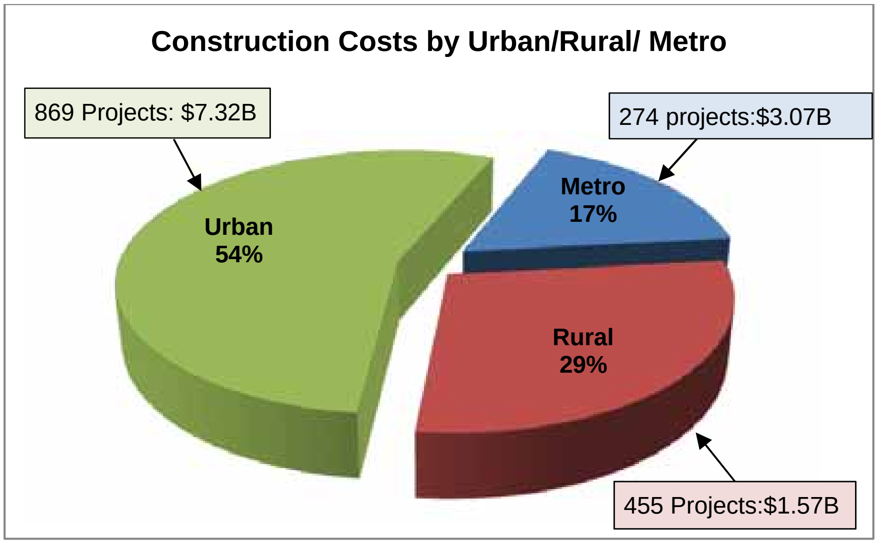


Figure 2.44: Summary of the TxDOT Construction Projects by Urban/Rural/Metro County

Prior to the analysis, several assumptions were examined to justify the use of linear regression models, including (1) linearity, (2) independence, (3) homoscedasticity, and (4) normality. To test conformity with linearity, an initial linear relationship between independent variables and dependent variables was performed. The results found that there were linear relationships between construction costs, and duration, indicating R^2 of 0.341. The residuals are plotted as shown in Figure 2.45.

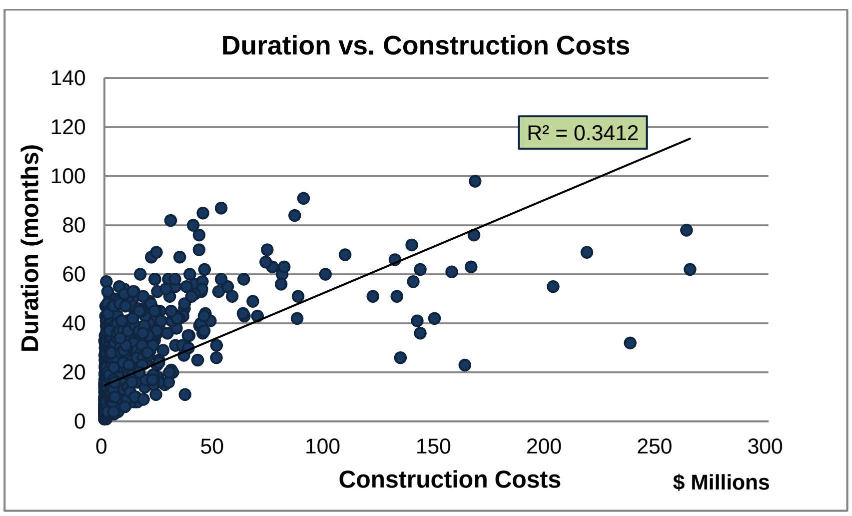


Figure 2.45: Scatter Plots of Duration vs. Construction Costs (Before Transformation)

According to the scatter plots, however, the distributions of independent and dependent variables seemed to be substantially skewed, which violated the assumption of a normal distribution. This violation of normality can frequently increase the likelihood of either a Type I or II error. Therefore, transformation of these variables is essential for normal distribution of residuals. To spread the data points more uniformly, CE costs and construction costs data were transformed using the logarithm function. This log transformation is commonly used for positive and non-zero data. As a result of log transformation, the residuals are normally distributed by indicating that the skewness is in the range of –1 to 1 and kurtosis is between –1 and –1. Table 2.23 shows the summary statistics of the dataset. In addition, the scatter plots of the residuals after log transformation are also presented in Figure 2.46.

Table 2.23: Statistics of the Construction Project Dataset

Variable	N	Min	Max	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
LogC_Costs	1598	4.16	8.42	6.2466	0.69496	.376	0.061	0.060	0.122
LogDuration	1598	0.00	1.99	1.1120	0.34457	-.089	0.061	-0.352	0.122

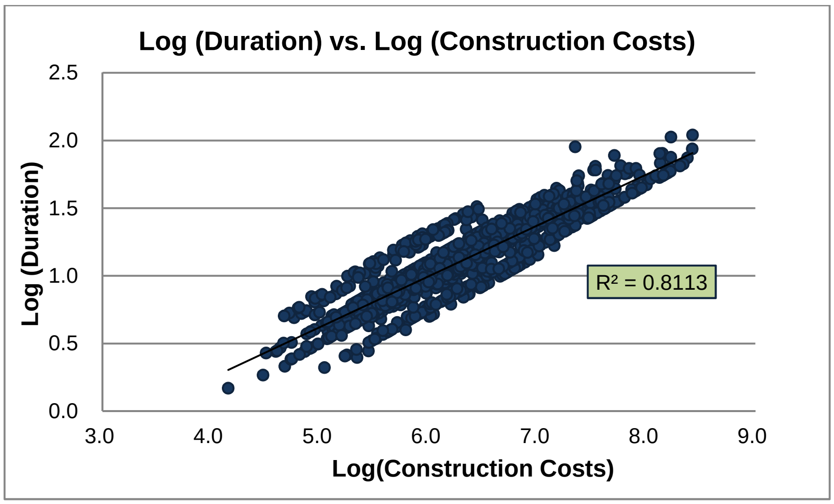


Figure 2.46: Scatter Plots of Duration vs. Construction Costs (After Transformation)

For the purpose of the duration of construction projects, 1598 CCSJ projects were used. To identify the impact of regional characteristics on the models, the degree of urbanization (rural, urban, metro counties) was also taken into account. The proposed duration model is a log-linear relationship of the form as shown in Equation 2.5:

$$\log(y_{\text{Duration}}) = \beta_0 + \beta_1 \times \log(x_{\text{constr cost}}) + \beta_2 \times x_{\text{proj type}} + \beta_3 \times x_{\text{proj type}} + \beta_4 \times x_{\text{proj type}} + \beta_5 \times x_{\text{urbanization}} + \beta_6 \times x_{\text{urbanization}} \qquad \text{(Eq. 2.5)}$$

To examine the relationships, stepwise multivariate regression analyses were conducted using a statistical software package (SPSS® 19.0). To compare the impacts of project type, degree of urbanization, and construction cost on duration, the regression analysis designated overlay (OV) and urban counties as reference variables. This analysis estimated the span duration in months from first to last payment. The result yields a significant model, F (19, 1578)

=127.979, p<0.001, Adjusted R square = 0.602. Table 2.24 summarizes the significant variables in the model.

Table 2.24: Regression Model for Duration with Different Project Types

Variables	Coefficients (B)	Std. Error	P-value
(Constant)	-1.682	.067	.000
LogC_Costs	.409	.010	.000
LSE	.578	.035	.000
HPR	.523	.218	.017
TS	.508	.038	.000
HES	.432	.079	.000
MSC	.327	.020	.000
BWR	.325	.033	.000
TPD	.287	.127	.025
UGN	.283	.068	.000
BR	.275	.021	.000
RER	.231	.024	.000
SFT	.225	.022	.000
WNF	.185	.025	.000
NNF	.174	.036	.000
RES	.151	.051	.003
INC	.130	.036	.000
CNF	.122	.056	.029
WF	.106	.039	.007
Metro	.035	.015	.019

In this model project construction cost, project type, and degree of urbanization account for about 60.2% of the variance in span duration. It is found that construction cost has a significantly positive effect on duration, with a coefficient of 0.409 for Log (Construction Cost). Thus, duration tends to increase as project size increases with a power factor of 0.409, confirming the log-normal distribution. Metro projects have a longer duration by a factor of 0.035 compared to those of urban and rural counties. These coefficients give a model for each project type as shown in Equation 2.5:

$$\begin{aligned} \text{Log(Duration)} = & -1.682 + 0.409\times\text{Log(Construction Costs)} + 0.578\times\text{LSE} + 0.523\times\text{HPR} + \\ & 0.508\times\text{TS} + 0.432\times\text{HES} + 0.327\times\text{MSC} + 0.325\times\text{BWR} + 0.287\times\text{TPD} + \\ & 0.283\times\text{UGN} + 0.275\times\text{BR} + 0.231\times\text{RER} + 0.225\times\text{SFT} + 0.185\times\text{WNF} + \\ & 0.174\times\text{NNF} + 0.151\times\text{RES} + 0.130\times\text{INC} + 0.122\times\text{CNF} + 0.106\times\text{WF} + \\ & 0.035\times\text{Metro} \end{aligned} \quad \text{(Eq. 2.6)}$$

The fitted lines estimated by the model are shown in Figure 2.47. The lines are for the project types as listed earlier. In particular, project types that were not included in the model were grouped as others. Each line is plotted only for the observed range of project construction cost for that project type. Figure 2.48 shows the data zoomed in to the $5 million construction cost range because some of the projects (i.e., TPD, and HES) are comparatively smaller in construction cost. The graphs indicate that, as construction costs increase, duration also increase, but at different rates for different project types.

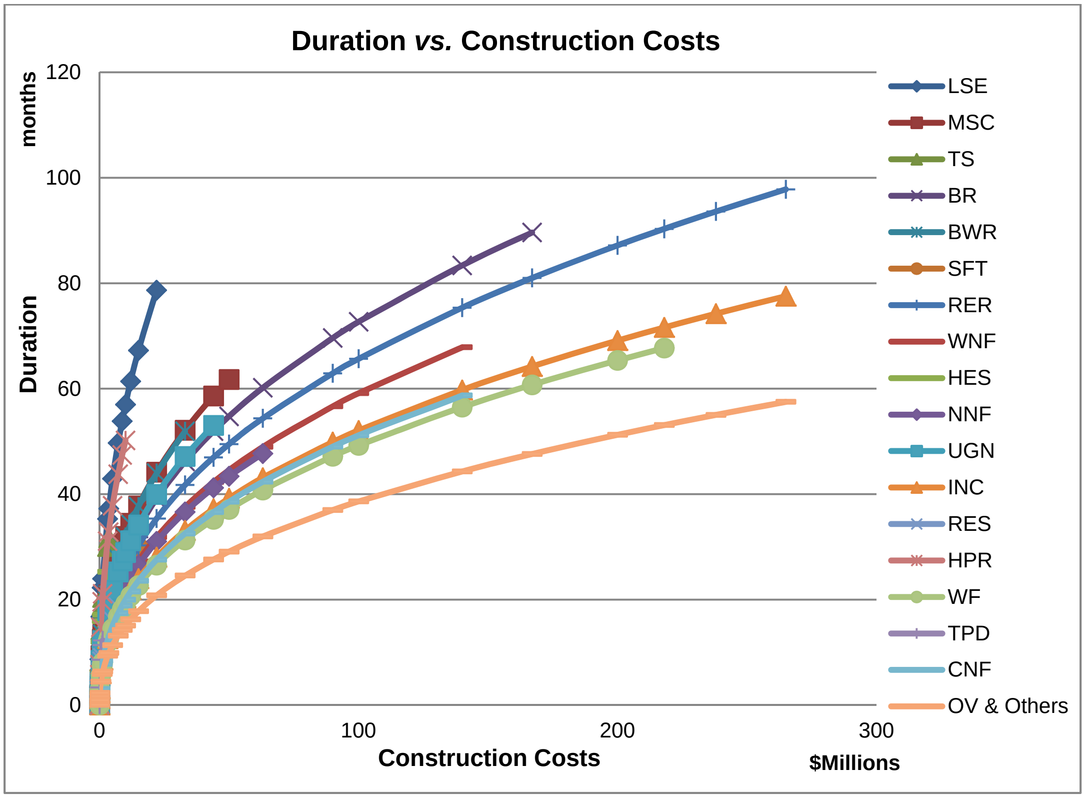


Figure 2.47: Graphs for Construction Costs vs. Duration by Project Type

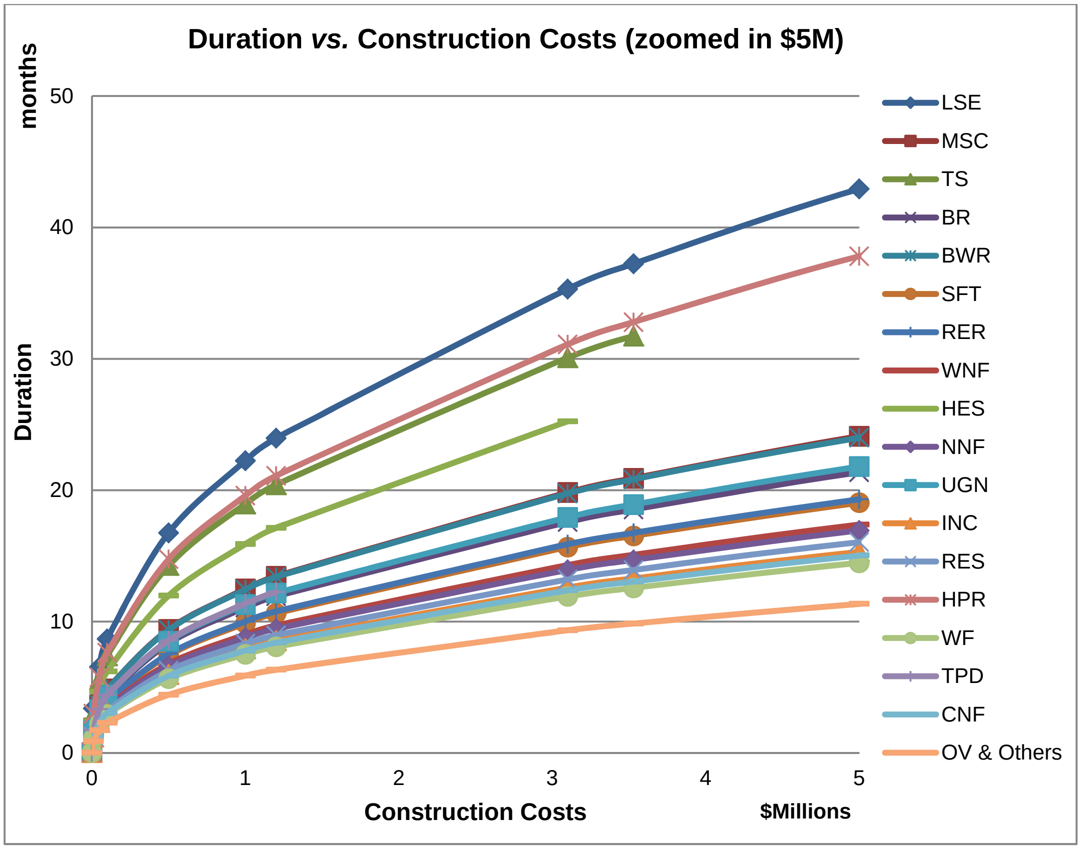


Figure 2.48: Graphs for Construction Costs vs. Duration by Project Type (Zoomed)

2.4.7 Seasonal Variation Analysis

Using a dataset of construction payments, the research team calculated the average proportion of the projects performed by TxDOT Regions during various months of the year. After analyzing the amount of work performed, the research team found that more construction work was performed in summer months between June and Oct and that the difference between 'busy' and 'lean' construction was most pronounced in the West region of the State and the South & East regions had the least variation. Table 2.25 describes the average proportion of the work done by region over the year.

Table 2.25: Average Proportion of the Work Performed by Region

Region	Month												Sum
	01	02	03	04	05	06	07	08	09	10	11	12	
All	0.068	0.066	0.059	0.074	0.081	0.085	0.107	0.114	0.095	0.100	0.085	0.065	1.000
East	0.074	0.075	0.061	0.078	0.080	0.080	0.098	0.101	0.091	0.105	0.088	0.070	1.000
North	0.068	0.067	0.059	0.077	0.072	0.089	0.105	0.112	0.097	0.098	0.085	0.072	1.000
South	0.075	0.069	0.067	0.074	0.082	0.078	0.088	0.110	0.091	0.103	0.092	0.071	1.000
West	0.054	0.053	0.051	0.066	0.089	0.095	0.138	0.134	0.101	0.096	0.075	0.049	1.000

Moreover, these data were also analyzed using the percentile values (0–33%, 33–67%, and 67–100%) to determine peak, normal, and off-peak months. Table 2.26 shows the percentile of the average proportion of the work performed according to region.

Table 2.26: Statistics for Seasonal Category

Region	Off-Peak Season	Shoulder Season	Peak Season
	Lower 33%	50%	Upper 33%
All	0.0739	0.0801	0.0908
EAST	0.0754	0.0802	0.0876
NORTH	0.0717	0.0765	0.0892
SOUTH	0.0742	0.0776	0.0883
WEST	0.0537	0.0754	0.0948

The patterns of the amount of the work performed were clearly seen as shown in Figure 2.49. For example, western part of the Texas had the highest variances over the year, compared to other parts such as east, north, and south parts. During the winter months, a small amount of projects was performed, while it was dramatically increased after June. Similar patterns were also found in other parts of the Texas (east, west, and north), even though the variance was not as much as that of the western part.

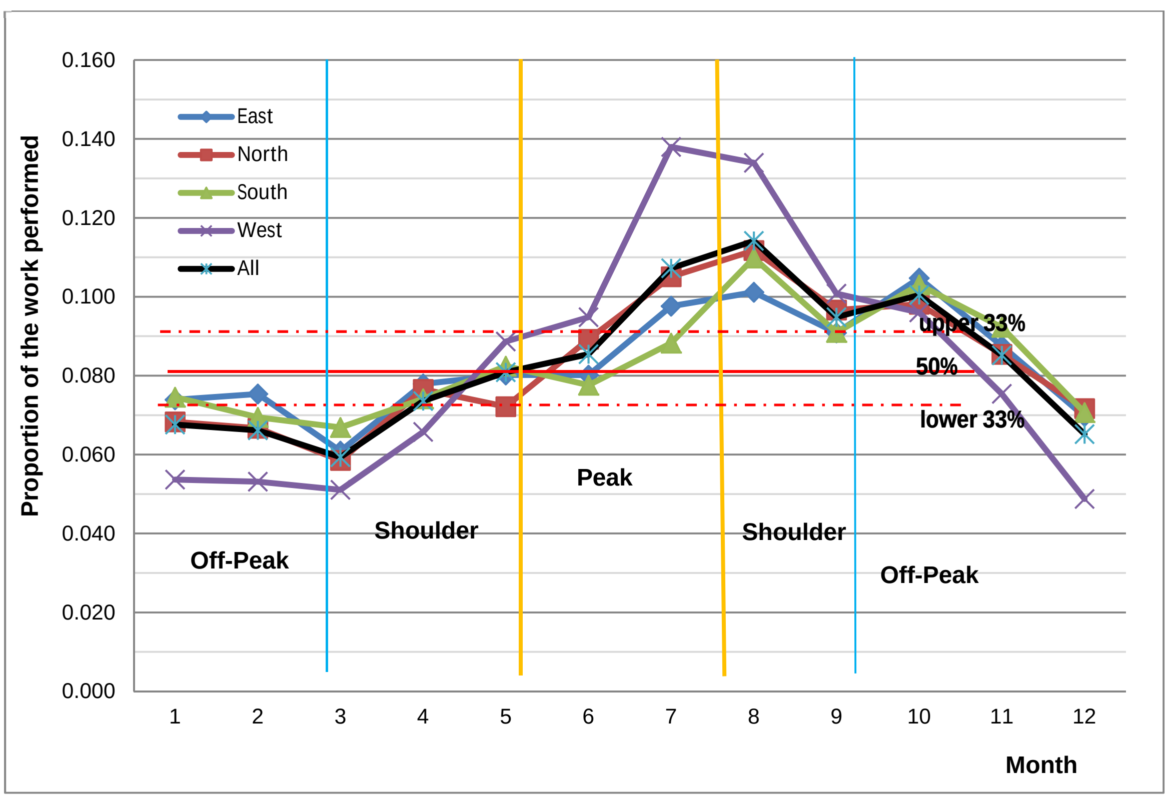


Figure 2.49: Seasonal Variation in the Amount of Construction by Region

Based on the trend of work performed and percentile values of the average amount of work performed, a year is broken down into three categories: peak, off-peak, and shoulder seasons. These categories are defined below:

- **Peak season**: the proportion of the work performed is above upper 33% and the slopes are dramatically increasing and decreasing around peak areas: *Jun., Jul., Aug, and Sep*.
- **Off-peak season**: the average proportion of the work performed is below lower 33% and the slopes are steadily decreasing until the lowest point: *Dec., Jan., Feb., and Mar*.
- **Shoulder season**: the average proportion of the work performed is between 33% and 67% and the slopes are steadily increasing or decreasing: *Apr., May, Oct., and Nov*.

To determine seasonal factors, the average proportion of work performed during each seasonal period was calculated. The ratios between those two average numbers indicated seasonal factors as shown in Table 2.27.

Table 2.27: Seasonal Factors

Region	The Average Proportion of Work Performed			Seasonal Factors		
	Peak	Shoulder	Off-peak	*Peak/ Shoulder*	*Off-Peak/Shoulder*	*Peak/Off-peak*
EAST	0.0924	0.0876	0.0700	1.0552	0.7986	1.3214
NORTH	0.1007	0.0831	0.0663	1.2121	0.7981	1.5187
SOUTH	0.0917	0.0880	0.0704	1.0421	0.8003	1.3022
WEST	0.1169	0.0815	0.0517	1.4348	0.6340	2.2629
All	0.1004	0.0850	0.0646	**1.1811**	**0.7595**	**1.5551**

The seasonal variance analysis is significant since it clearly depicts that the workforce needs for construction inspection are not constant during the year but vary by as much as a factor of 2.2 between the peak and the low construction seasons. Therefore, the output from the statistical model cannot be linearly spread and a mechanism to account for peak construction workload needs to be established.

2.4.8 Comparison with TxDOT's Construction Staffing Model

During the course of this research project, CTR reviewed the TxDOT Construction Workforce Staffing Model (CWSM). This model maintained by the Construction Division of TxDOT is used for estimating construction workforce required to inspect, supervise and manage all active and upcoming construction projects. The following summarizes the strengths and deficiencies of the model.

The CWSM estimates the staffing numbers in three different categories:

1. Number of inspectors required to inspect the projects,

2. Number of managers needed to manage the construction staff at the Area Office level, and,
3. The support staff needed to ensure compliant record-keeping, materials testing at Area Office and District laboratories; District Director of Construction and his/her staff.

The CWSM estimates inspector counts using productivity assumptions in terms of dollar value of construction work that can be inspected per month per inspector. The base value for this is $250,000 per inspector per month. This base productivity number was calculated using data from 2008 and is adjusted using TxDOT's Highway Cost Index (HCI) when estimating inspector counts using construction costs for future projects. The CWSM refines the inspector counts by eliminating over-estimation for Seal Coat (SC), Overlay (OV) and Bridge Rehabilitation (BR) projects. This is needed since SC and OV projects can consist of many smaller jobs that if modeled using the standard productivity approach would yield an over-estimation. Similarly, inspector needs for the BR projects is calculated using a modified approach whereby a $5M BR project is assigned a single inspector and anything above that is assigned 2 inspectors during the life of the project. Although in rare instances this does lead to under-calculations at the project level whereby large BR projects may go understaffed.

In addition, to directly inspecting and managing projects, TxDOT has oversight role on locally let projects where federal transportation funds are utilized, however, entities other than TxDOT are responsible for managing and inspecting construction work. For these projects, CWSM estimates the inspector requirements using a factor which yields a productivity of $2.5M per inspector per month. Similar approach was used to calculate inspector needs for projects that use non-traditional methods of project delivery, i.e., Comprehensive Development Agreements, Design-Build projects and others. Current version of the model does not contain data for these types of projects.

However, the CTR construction inspector staffing model estimated inspector needs primarily based on the CE cost model developed (as detailed under 2.4.1) by utilizing the historical data from TxDOT's Financial Information Management System. As discussed, the basic concept of computing inspector needs is by calculating total CE costs and converting them to FTE counts using average salary information. Using the CE model, CE costs can be estimated using the construction cost estimates of the construction projects in the portfolio and their project classification (project type). The total estimated CE costs then are spread over the construction duration or contract duration. Then, monthly CE costs were divided by an average monthly salary, which produces the number of inspector needs per month.

Using the project list of November 2010, a comparison of the results of the CST and CTR models was conducted. Overall, the CST staffing model overestimated the inspector needs, compared to the CTR staffing model. The CST model estimated 1,879 inspectors with about $11.1 billion of construction projects on Jan 2012. The number of inspectors drops to 1,514 in six months, and then slightly increases until July 2013. On July 2015, 982 inspectors were estimated with $ 5.9 billion of construction volume. On the other hand, the CTR model estimated 1,378 inspectors for the same portfolio of construction contracts on Jan. 2012. The number increases to 1,594 until Jan. 2014 and then, decreases to 939 on July 2015. Figure 2.50 shows comparison of CE models between CST and CTR models in terms of CE inspector needs.

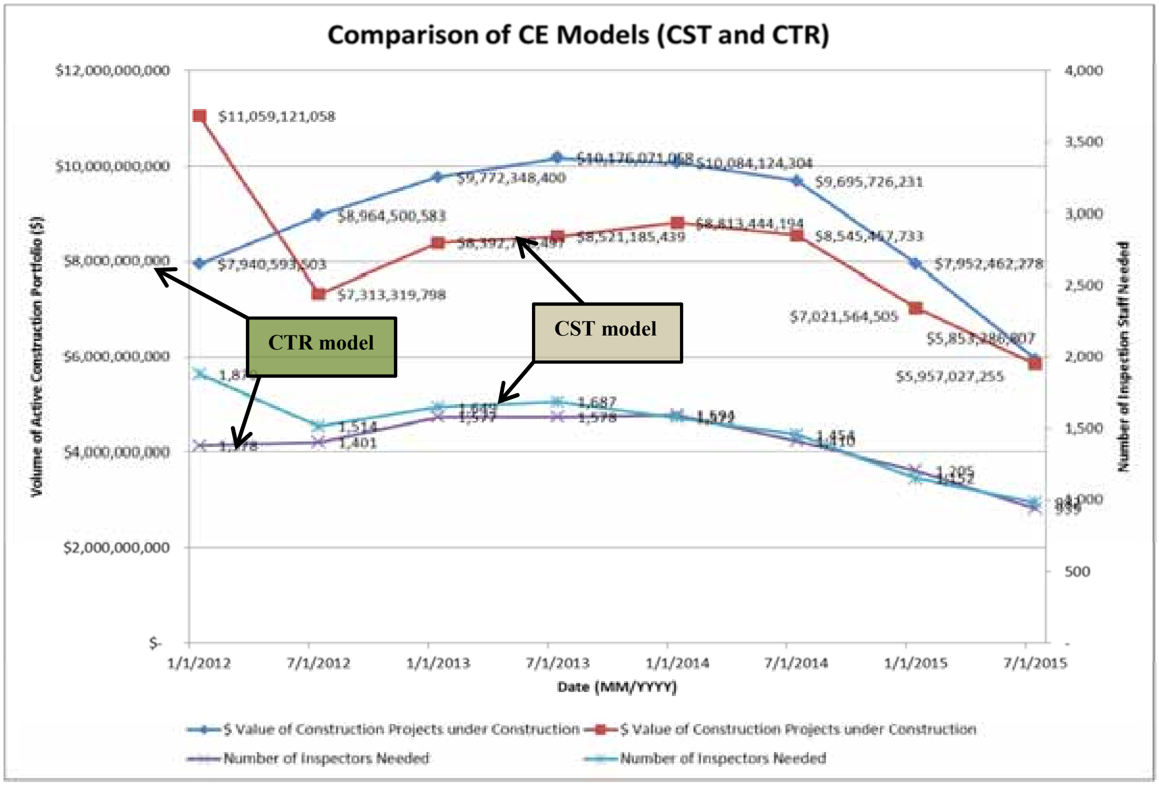


Figure 2.50: Comparison of CE Inspector Needs (CST vs. CTR Models)

2.4.9 Conclusions and Recommendations

The primary purpose of this study was to assess the staffing requirements for TxDOT's 4-year portfolio of construction projects of contracts already under construction and those that are expected to let for construction in the next four years. In order to do so, the financial costs incurred during the construction phase and recorded in the FIMS database for the past portfolio of projects was obtained from TxDOT in November 2010, and examined. A stepwise regression model for CE costs was developed to estimate CE cost based on the various project types and dollar value of construction work. The results indicated that construction cost, and project type account for about 81.5% of the variance in CE costs, at the 95% confidence level. The model provided insights into the types and dollar value of construction projects that are most CE staff-intensive.

In addition, through an analysis of construction payouts by month, the variability in construction staffing needs was assessed to establish the seasonal variation in construction inspection staffing needs for various TxDOT regions.

The findings of this study provide a statistical model for TxDOT to estimate construction inspection staffing based on the summation of active and projected construction workload. In addition, it allows the decision-makers to assess this staffing need using the construction cost estimates and project types of the projects in the portfolio. Moreover, it allows for establishing construction inspection staffing needs when unique situations arise from the infusion of non-traditional funding. Since TxDOT relies for the most part on lowest-bid method for construction contractor selection and utilizes prescriptive specifications for ensuring the quality of the construction work, the burden for ensuring quality construction depends to a large extent on field inspection at the time of construction. Therefore, having adequate field inspection workforce is of significant importance in ensuring the quality of the constructed projects. In addition, this model will help improve efficiency in performing construction inspection by allocating construction inspection staff to each district based on the current and projected construction workload.

Chapter 3. Assessment of Durations and Staffing Needs for Environmental Approvals

3.1 Introduction

Task 13 (FY12): Assessment of durations and staffing needs for environmental approvals

The objective of this task was to provide an independent assessment of work conducted by a TxDOT team on the durations and staffing needs for various levels of environmental document types required for TxDOT projects. Where necessary, the researchers gathered additional data and conducted additional analyses to refine the existing estimates, made recommendations for incorporating the results into the TxDOT PDP-2012 effort, and assisted with the manpower needs assessment for the environmental phase of the project development process.

S.B. 1420 (82R) specifies that, "the environmental review document for each highway project will be completed no later than one year prior to the date planned for publishing notice to let the construction contract for project." This legislative requirement will most likely require additional resources for the environmental phase, and the results of this study will be used to aid in determining the additional staffing requirements for complying with the legislative requirements.

A TxDOT team that included Susan Jaworski and Rudy Hermann had collected data on the durations of various types of environmental document types, from Blanket Categorical Exclusions to full Environmental Impact Statements, as well as man hours charged and costs accrued. The data included projects from the last 10 years, by CSJ. After cleaning of the data to remove inconsistent numbers and outliers, the team presented the results as averages and statistical spreads. TxDOT Administration requested that CTR examine these results, conduct additional analyses as needed, and provide recommendations for utilizing the results in the Department's manpower management systems.

CTR met with available members of the TxDOT team that gathered and analyzed the data, conducted an independent review and analysis of the results, and determined what refinements, if any, were needed. The researchers gathered additional data as necessary to refine the analyses and the results with additional variables (where correlations could be established) in collaboration with TxDOT staff. Recommendations included steps for incorporating the results into the Department's PDP-2012 efforts for estimating internal and external staffing needs.

3.2 Task 13 Work Plan

The work plan for this task included the following sub-tasks:

- Collect the data and results developed by the TxDOT team.
- Independently review and analyze the data.
- Identify additional variables, if any, to refine the analysis and results
- Meet with available team members and share the analysis and results. Collect feedback from the TxDOT team.

- If necessary, gather additional data from the Environmental Division, FIMS, etc., and conduct analyses of environmental durations and manpower needs by environmental document type.
- Submit draft results of findings, presenting analyses of durations, manpower needs and cost by environmental document type, by November 30, 2011.
- Continue refining results and provide quarterly updates.
- Submit final recommendations by August 2012.

3.3 Preliminary Results

The following draft results were submitted to the TxDOT Environmental Task Force headed by Lubbock District Engineer Doug Eichhorst on September 27, 2011, and to the TxDOT Modernization Task Force on October 6, 2011.

The objective of this task was to estimate the man hours required to complete the work for the environmental phase of the project development process. To do this, the research team acquired data from TxDOT districts, TxDOT's Design and Construction Information System (DCIS), and TxDOT's Financial Information System (FIMS)

A 'select' list of project CSJs was provided to the researchers. These were projects that the districts had submitted. A total of 167 CSJs were reviewed. For each project the districts provided the type of Environmental Document that was required. Table 3.1 is a summary of the number of projects with each Environmental Document Type.

Table 3.1: Number of Projects of Each Environmental Document Type

Document Type		**Number of CSJs**
BCE	Blanket Categorical Exclusion	44
CE	Categorical Exclusion	42
PCE	Programmatic Categorical Exclusion	44
EA	Environmental Assessment	32
EIS	Environmental Impact Statement	6
TOTAL		**167**

The PDP (Project Development Plan) codes for the projects were checked. Table 3.2 is a summary of the number of CSJs with each PDP code.

Table 3.2: Number of Projects of Each PDP Code

PDP Code	Number of CSJs
PL12	31
INACT	10
LDP	6
PL13, P14PE	3 each
UNATH	2
PL 15, UTP2, 4BL	1 each
(missing) = 65%	109
Total	**167**

When the project CSJs were compared to DCIS, 163 had a matching CSJ in DCIS. It is not clear why the other four had no match. Most of the projects were let prior to FY 12, but two were rejected: one had an Actual Let Date of 12/1986, and the other a District Estimated Let Date of 07/99 (but no Actual Let Date). The other project letting dates ranged from 07/2004 to 12/2060, i.e., some of them are not yet let, so may incur additional charges to the Environmental Function Code 120 series.

To analyze environmental man hours and costs, the researchers requested data from FIMS. For each of the CSJs, the Function Code 120 series charges, namely, Life-to-date (LTD) man hours (assumption: Hours only reflect the TxDOT staff hours charged under FC 120 to these CSJs), and dollars (note: $ include consultant costs as well TxDOT costs—not separated). This data was received on 09/14/2011.

Of the 167 CSJs, 39 had $0 charges under FC 120, all of them BCE, CE, PCE or EA projects. It is possible that the charges went to another or an 'ancestor' CSJ. Alternatively, since some of the projects have not yet been let, the charges may not have been properly allocated. These data issues depict the challenges in developing statistics using data from DCIS/FIMS.

The data on dollar charges were given with and without overhead. The overhead additive is applied only to dollar charges, not to man-hours. The following figures are box-plots of the range of these charges for each Environmental Document Type (EDT). Figure 3.1 shows the dollar amounts without overhead for each EDT. EIS are by far the most expensive, with the two middle quartiles ranging from about $700,000 to $2.5 million, with the mean very close to the higher figure. BCE and PCE are the least costly.

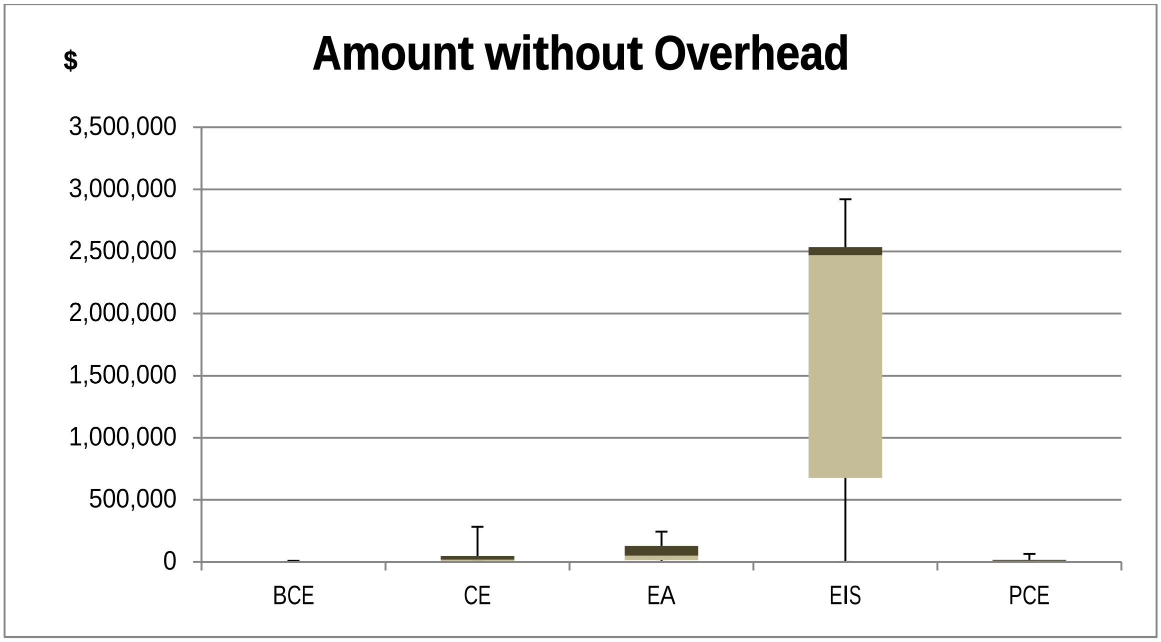


Figure 3.1: Dollar Amounts without Overhead for Each Environmental Document Type

Figure 3.2 shows the same data zoomed in for non-EIS documents. After EIS, in relative order of costs, the rank is EA, CE, and PCE, with BCE the lowest. The two middle quartiles for EA range from about $15,000 to $130,000, with a mean near $50,000. BCE is the least costly.

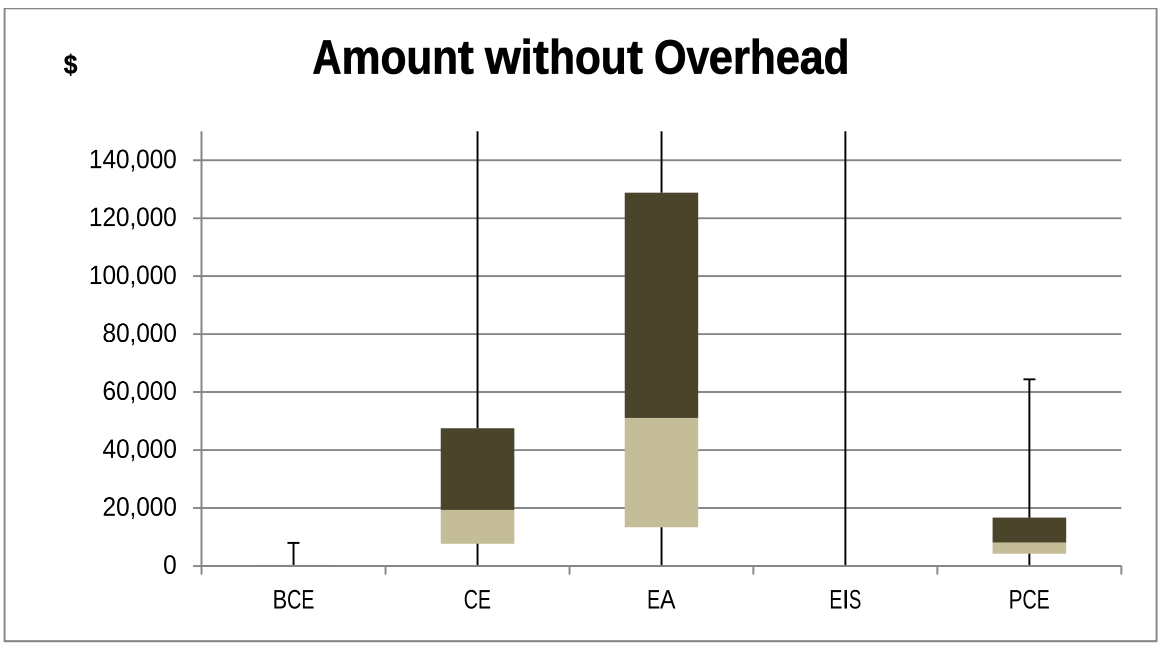


Figure 3.2: Dollar Amounts without Overhead for Each Environmental Document Type—Zoomed

Table 3.3 is the quartile data in tabular form.

Table 3.3: Dollar Charges without Overhead for Each EDT

BCE	CE	EA	EIS	PCE
7,982	283,149	244,179	2,919,423	64,422
348	47,566	128,876	2,534,609	16,728
0	19,330	51,135	2,469,131	8,170
0	7,677	13,406	675,082	4,304
0	0	0	0	0

Figure 3.3 shows the range of TxDOT (in-house) hours for each EDT. As before, EIS are the most work-intensive, with the two middle quartiles ranging from about 750 to 1050 hours, with the mean close to 900 hours. After EIS, in relative order of labor, the rank is same as before: EA, CE, and PCE, with BCE the lowest. The two middle quartiles for EA range from about 200 to 900, with a mean near 500.

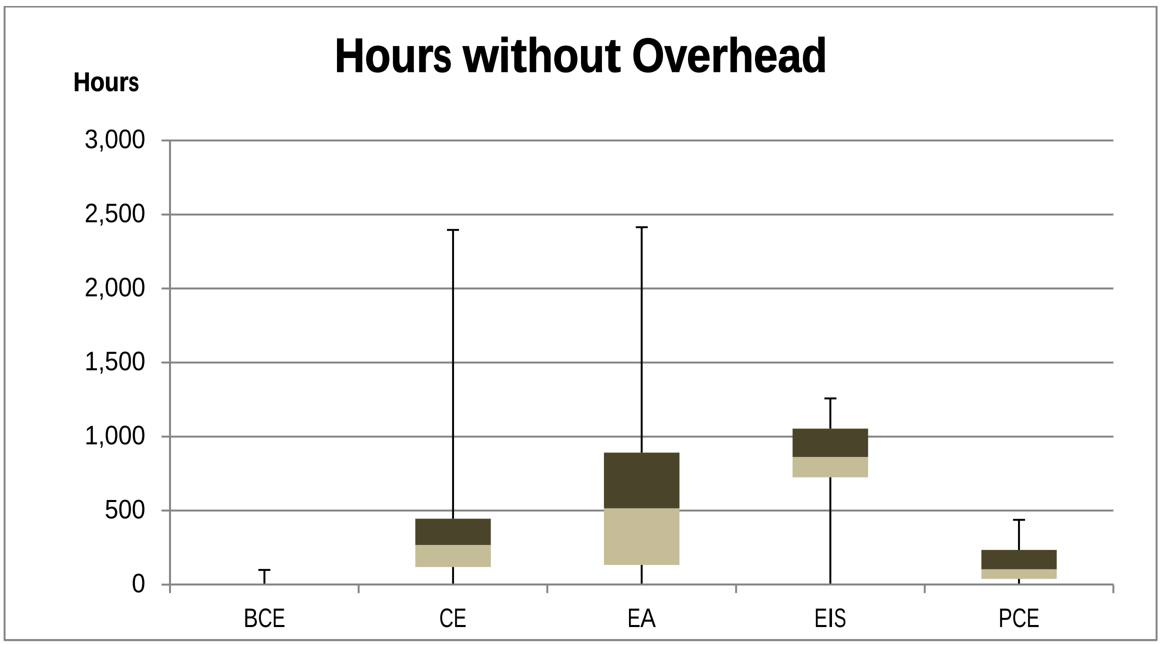


Figure 3.3: Range of In-house Man Hours for Each Type of EDT

This preliminary analysis of 167 CSJs found that the list of 'selected' projects had some errors in CSJ numbers, PDP codes, and letting dates. These were projects that had been selected by the districts. There was significant variability in the $ and man hour charges, and almost 25% of the projects had zero charges. The research team recommended that to remove any biases and to provide a larger and more consistent data set, data on all projects that were actually let in FY 10–11 should be obtained and analyzed.

3.4 Results of Statistical Analysis

Data was obtained from TxDOT on 5731 CSJs that went to letting in FY 10–11. Of these, 525 had no data as to the EDT, if any, that was prepared. Of the remaining 5206 CSJs, another 958 were not found in the P6 database that was used to extract EDT, leaving a total of 4248 with EDT data. The number of CSJs with each type of EDT is shown in Figure 3.4.

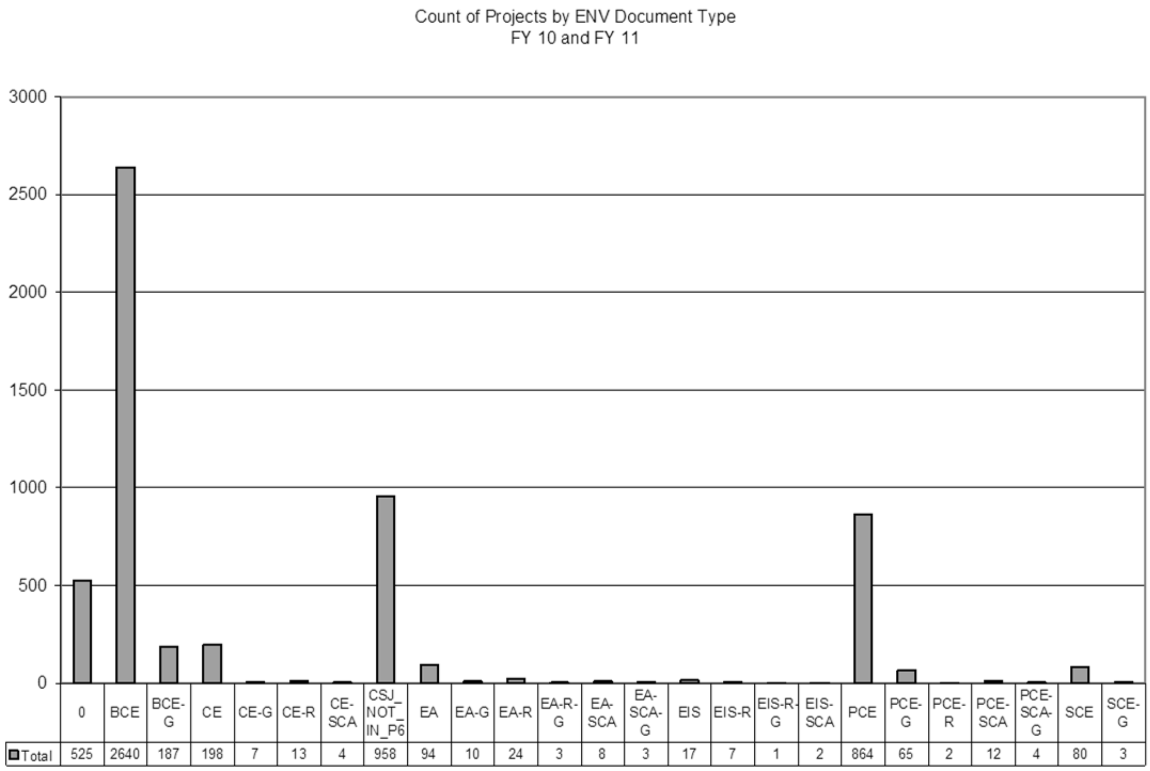


Figure 3.4: Number of CSJs with Each Type of EDT in FY 10–11 Lettings

BCE and BCE-G comprise 67% of the CSJs, followed by PCE and sub-types with 22%. CE and sub-types make up 5%, while SCE and sub-types are another 2%. EA and sub-types total 3.3%, and EIS are less than 1% of all CSJs. Thus, looking at the costs and man-hours in the preliminary analysis, it is seen that frequency of a type of EDT is inverse to effort required. EIS are rare but labor-intensive, while BCE are very common but low-effort.

Data was obtained from FIMS on man hours and LTD charges for the projects in the dataset. Of the 4248 CSJs, another 1134 had to be eliminated because of missing project information, leaving 3114 CSJs for analysis.

3.4.1 Man Hours for Environmental Documents

Statistical analysis was performed to analyze the man hours required for Environmental Documents. The initial test was for whether man hours varied with project size (CSJ construction cost estimate) and project location (Metro/Urban/Rural). A model of the form

$$\textbf{Log}_{10}\textbf{Env. Hours = (Constant A) + B* Log}_{10}\textbf{Construction Cost + Location Factor + Project Type Factor + Document Type Factor}$$

was postulated, where location factor, project type factor, and document type factor were additives to the log model (and multipliers to a normal model). Using stepwise regression for variable entry, the model in Table 3.4 was generated.

Table 3.4: Initial Model of Man Hours for Environmental Documents

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
6	0.454921	0.206954	0.205421566	0.522618		
f	Predictors: (Constant), LogConstCost, EA, CE, Metro, BCE, RES					
Coefficients(a)						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
6	(Constant)	0.44968	0.090598554		4.963438	7.3E-07
	LogConstCost	0.203152	0.015275109	0.243075	13.29955	2.71E-39
	EA	0.540217	0.044084912	0.218979	12.25402	9.5E-34
	CE	0.349401	0.033770586	0.17351	10.34631	1.09E-24
	Metro	-0.19815	0.03023972	-0.10584	-6.55267	6.59E-11
	BCE	-0.4283	0.0754488	-0.09094	-5.67666	1.5E-08
	RES	-0.17296	0.048712582	-0.05748	-3.55058	0.00039
a	Dependent Variable: LogEnvHours					

This model can be read as

$$\textbf{Log}_{10}\textbf{Env. Hours = 0.4497 + 0.2032 Log}_{10}\textbf{Construction Cost – 0.1982 Metro - 0.4283 BCE - 0.1730 RES + 0.5402 EA +0.3494 CE}$$

Or, in normal terms,

$$\textbf{Env. Hours = 2.8163 * (Construction Cost)}^{0.2032}\textbf{ * 3.4691 EA * 2.2356 CE *0.3730 BCE * 0.6337 Metro * 0.6715 RES}$$

Thus, Environmental Document man hours increases as construction cost increases, but tapers off. There is a 3.4691 multiplicative effect for EA over other EDT, a 2.2356 multiplier if CE, and a 0.3730 multiplier if BCE. Metro projects require 63% of the hours of urban and rural projects. RES (restoration projects) take 67.2% of the man hours of other project types.

Note that the man hours for the EIS document type is found to be statistically not different from PCE and SCE types, mainly because there are only 7 EIS in the data, and the range of hours is from 66 to 1132. The adjusted R^2 of the model is only 20.5% and the standard error is 0.5226, quite high. For these reasons the researchers tested a slightly altered model, in which each project type was allowed to have its own fitted line.

The altered model is of the form

Log_{10}Env. Hours = (Constant A) + B* Log_{10}Construction Cost * Project Type Factor + Location Factor + Document Type Factor

Table 3.5 gives the results. This model can be read as

Log_{10}Env. Hours = 0.3323 + 0.2246 Log_{10}Construction Cost + 0.5095 EA + 0.3368 CE + BCE*(2.3168 -0.4817 Log_{10}Construction Cost) – 0.2055 Metro + RES*(- 0.2031 +0.2930 Log_{10}Construction Cost) +SFT*(0.6631 – 0.1214 Log_{10}Construction Cost)

Or, in normal terms,

BCE Documents: **Env. Hours = 445.71 * (Construction Cost)$^{-0.2571}$ * 0.6231 Metro**

With adjustments if EA or CE for the following project types:

RES Projects: **Env. Hours = 0.0201 * (Construction Cost)$^{0.5176}$ * 3.2325 EA * 2.1719 CE * 0.6231 Metro**
SFT Projects: **Env. Hours = 9.90 * (Construction Cost)$^{0.1032}$ * 3.2325 EA * 2.1719 CE * 0.6231 Metro**
All Others: **Env. Hours = 2.1493 * (Construction Cost)$^{0.2246}$ * 3.2325 EA * 2.1719 CE * 0.6231 Metro**

Again, Environmental Document man hours increase as construction estimate increases, but tapers off, the rates being different for BCE documents, RES projects and SFT projects. For all project types, there is a 3.2325 multiplicative effect for EA over other EDT, and a 2.1719 multiplier if CE. Metro projects require 62% of the hours of urban and rural projects.

Table 3.5: Revised Model of Man Hours for Environmental Documents

Model	R	R Square	Adj. R Square	Std. Error of the Estimate		
10	0.463337	0.214681	0.212149205	0.5204		
j	Predictors: (Constant), LogConstCost, EA, CE, Metro, CC_BCE, RES, BCE, CC_SFT, SFT, CC_RES					
Coefficients(a)						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
10	(Constant)	0.33229	0.100806924		3.296297	0.000991
	LogConstCost	0.224603	0.016879253	0.268741	13.30643	2.49E-39
	EA	0.509545	0.044651244	0.206545	11.41165	1.41E-29
	CE	0.336841	0.033870064	0.167272	9.945081	5.82E-23
	Metro	-0.20548	0.030194986	-0.10975	-6.80494	1.21E-11
	CC_BCE	-0.48165	0.131371826	-0.58512	-3.6663	0.00025
	RES	-2.03016	0.923641772	-0.67467	-2.198	0.028023
	BCE	2.316758	0.751980708	0.491924	3.080874	0.002082
	CC_SFT	-0.12143	0.03910644	-0.47563	-3.10508	0.001919
	SFT	0.663145	0.229523687	0.444519	2.889222	0.003889
	CC_RES	0.293004	0.146573168	0.614089	1.999027	0.045693
a	Dependent Variable: LogEnvHours					

As before, the man hours for the EIS document type is found to be statistically not different from PCE and SCE types. These results are not intuitive. The adjusted R^2 of the model is only marginally better at 21.2% and the standard error is about the same, at 0.5204. For these reasons, it is concluded that the model may work for EA, CE and BCE document types, but cannot estimate EIS very well. The researchers then tested a model for document costs to see if there would be any improvement.

3.4.2 LTD Costs for Environmental Documents

Statistical analysis was performed to analyze the LTD (life-to-date) costs accrued for Environmental Documents. The initial test was for whether cost varied with project size (CSJ construction cost estimate) and project location (Metro/Urban/Rural). Following is a model of the form:

$$\mathbf{Log_{10}Env.\ Cost = (Constant\ A) + B^* \ Log_{10}Construction\ Cost + Location\ Factor + Project\ Type\ Factor + Document\ Type\ Factor}$$

was postulated, where location factor, project type factor, and document type factor were additives to the log model (and multipliers to a normal model). Using stepwise regression for variable entry, the model in Table 3.6 was generated.

Table 3.6: Initial Model of Costs for Environmental Documents

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
11	0.564565	0.318734	0.31631664	0.600323		
k	Predictors: (Constant), LogConstCost, EA, CE, Metro, BR, RES, BCE, BWR, Rural, PCE, SCE					
Coefficients(a)						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
11	(Constant)	3.048696	0.268908823		11.33729	3.2E-29
	LogConstCost	0.299759	0.018495752	0.289526	16.20694	9.11E-57
	EA	-0.49119	0.231504603	-0.1604	-2.12172	0.03394
	CE	-0.81939	0.23080171	-0.32863	-3.55018	0.000391
	Metro	0.318558	0.036652991	0.137426	8.691185	5.71E-18
	BR	0.203017	0.026231079	0.128756	7.739577	1.34E-14
	RES	-0.29753	0.056844705	-0.07986	-5.23408	1.77E-07
	BCE	-1.78129	0.245880482	-0.30548	-7.24455	5.45E-13
	BWR	0.290934	0.053482372	0.082504	5.439818	5.75E-08
	Rural	-0.10972	0.023347197	-0.07548	-4.69947	2.72E-06
	PCE	-1.24462	0.229873142	-0.72582	-5.41439	6.62E-08
	SCE	-1.18508	0.233764288	-0.39564	-5.06955	4.22E-07
a	Dependent Variable: LogEnvCost					

This model can be read as

$$\mathbf{Log_{10}Env.\ Costs = 3.0487 + 0.2998\ Log_{10}Construction\ Cost + 0.3186\ Metro - 0.1097\ Rural - 0.4912\ EA - 0.8194\ CE - 1.1851\ SCE - 1.2446\ PCE - 1.7813\ BCE + 0.2909\ BWR + 0.2030\ BR - 0.2975\ RES}$$

Or, in normal terms,

$$\mathbf{Env.\ Costs = 1118.66 * (Construction\ Cost)^{0.2998} * 0.3227\ EA * 0.1516\ CE * 0.0653\ SCE * 0.0569\ PCE * 0.0165\ BCE * 2.0824\ Metro * 0.7767\ Rural * 1.9540\ BWR * 1.5959\ BR * 0.5040\ RES}$$

Thus, Environmental Document costs increase as project construction estimate increases. Compared to the cost of an EIS, EA is 32.3% of that, CE is 15.2% of it, BCE is 6.5% of it, PCE is 5.7% of it, and BCE is 1.7% of the cost of an EIS. Environmental documents for Metro projects cost 2.08 times those of urban projects, while those for rural projects cost 78% of urban projects. Compared to other project types *of the same type, cost and document type*, BWR (bridge widening) documents cost 1.95 times, BR (bridge replacement) cost 1.6 times, and RES (restoration) cost 50%.

Figure 3.5 illustrates the model for each document type. The lines from the top are for EIS—Environmental Impact Assessment, EA—Environmental Assessment, CE—Categorical Exclusion, SCE—Special Categorical Exclusion, PCE—Programmatic Categorical Exclusion, and BCE—Blanket Categorical Exclusion. The last is barely visible at the very low end. The lines are plotted for the range of project costs observed for each document type.

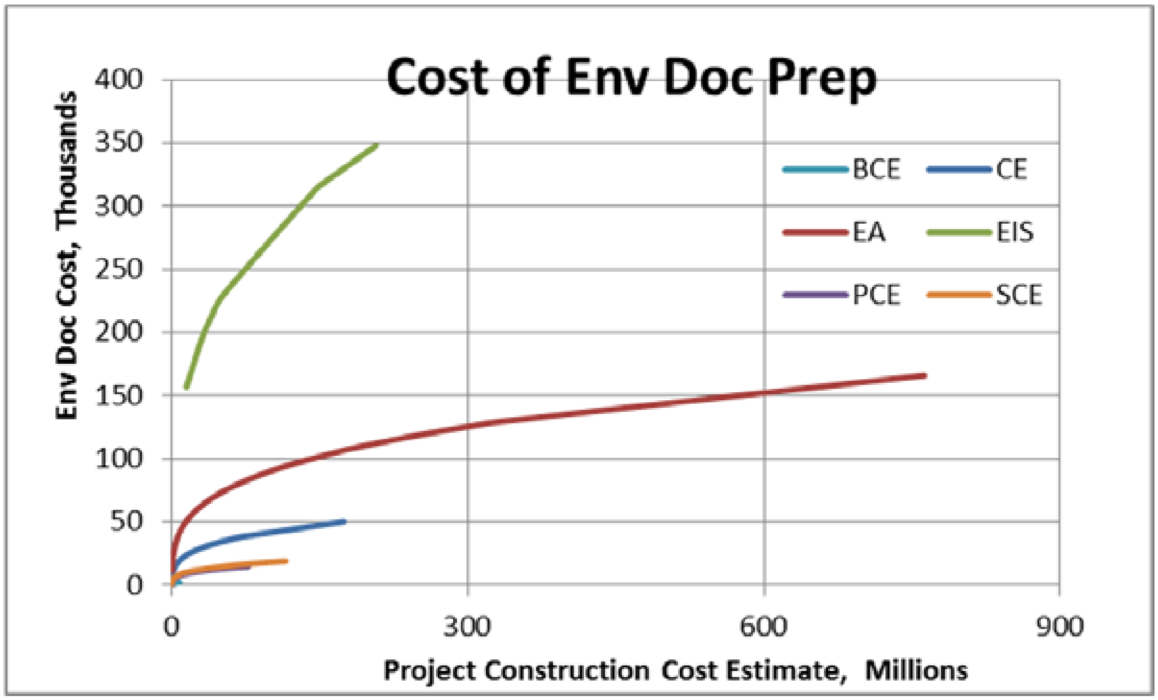


Figure 3.5: Cost of Environmental Document Preparation vs. Project Construction Estimate

Figure 3.6 gives the same information zoomed in for projects less than $100 million. In each case, document costs increase with project size. There are some adjustments to the estimates in the following circumstances:

1. If project location is Metro, multiply estimate by 2.0824. If Rural, multiply by 0.7767.
2. If project type is BWR (bridge widening), multiply document cost by 1.954 times. If BR (bridge replacement), multiply by 1.5959, and if RES (restoration), multiply by 0.504.

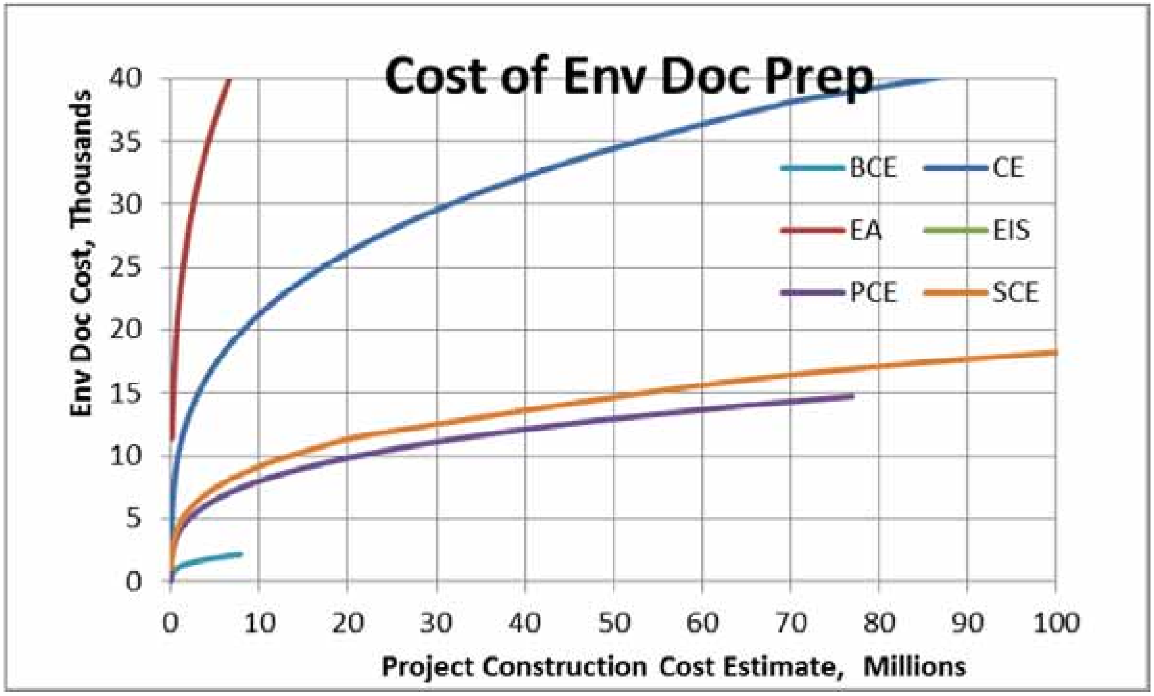


Figure 3.6: Cost of Environmental Documents vs. Project Construction Estimate—Zoomed

These results match well with the initial analysis, and capture some of the variance in costs across document types. The adjusted R^2 of the model is 31.6% and the standard error is 0.6003. The statistical modeling accounts better for the variance in document costs than the variance in hours across document types, but there is still a lot of variability that is unexplained.

3.5 Conclusion

The results of the statistical analysis may be used to estimate the cost of preparation of Environmental Documents. As a check, the hours model may be used, recognizing that it only estimates in-house hours. On the other hand the cost model includes both consultant-prepared documents as well as in-house work. As a result of these limitations, it is recommended that these results be used with caution, recognizing the inherent uncertainty in the data and the models.

Chapter 4. Development of a Spreadsheet Based Model of S101 Staffing Needs

4.1 Introduction

Task 14 (FY12): Development of a spreadsheet based model of S101 staffing needs for use by the TxDOT Modernization Team

The objective of this task was to develop a spreadsheet-based FTE staffing tool for computing TxDOT Strategy101 staffing needs. The function of the tool is to utilize as inputs the results of the CTR PE staffing study, CST construction staffing model and a scenario modeling tab for inputting potential additional funds by funding category. Using the inputs, the tool would allow for analyzing District project development and construction staffing needs. The objective of the tool was to allow TxDOT staff to utilize the results of the various staffing models within a spreadsheet environment and utilize these with the known and proposed funding scenarios that TxDOT staff may be asked to evaluate for impacts on TxDOT staffing and consultant needs.

TxDOT has been experiencing an uncertain overall funding picture due to declining funds available from the traditional federal and state revenue sources. The Texas legislature has responded by instituting a series of 'one-time' infusions using the Proposition 12 and Proposition 14 series bonds that have allowed the funding declines to be moderated. In addition, the Federal stimulus funds (ARRA) were another one-time infusion that provided a short-term bump in cash flow for constructing 'shovel-ready' type projects. The recently concluded 82nd legislative session approved the second tranche of Proposition 12 bonds that will require TxDOT to meet a combined letting obligation of approximately $8.4 Billion in the FY12 and FY13. However, the combination of declining revenue from traditional sources, blunted by the one-time infusion has caused uncertainty in the medium and long-term revenue forecasts and consequently the number of projects that can be developed and constructed based on the cash flow projections. This uncertainty impacts the staffing needs for developing, letting and managing design and construction projects and the staff needed to hire, manage and oversee the consultants used to augment the TxDOT staffing needs.

In FY 11 TxDOT asked CTR to develop models for predicting staffing needs, by collecting and analyzing historical productivity data. CTR developed and refined an initial set of models that can be used to predict staffing needs for a future portfolio of design and construction projects. In the present task, CTR utilized the developed models in conjunction with other existing staffing models for estimating S101 staffing needs. In addition, CTR developed additional models for scenario-based modeling at the funding category level for any proposed cash infusion. CTR also proposed, that if requested, the Texas State University consultant costs study results for estimating consultant needs and an existing TxDOT construction payout curve model to model CE staffing peaks would be incorporated.

4.2 Task 14 Work Plan

<u>Task 14A: Draft Automated Spreadsheet based S101 Staffing Model:</u>

- Analyze the output format of the CST staffing model. Identify efficient formats for exporting the output of the CST staffing model for use in the proposed S101 Staffing Model.

- Review the format of the existing PE staffing models developed by CTR for use in the automated S101 Staffing Model.
- Develop additional models to predict staffing at the funding category level when granular project level information is not available.
- Submit S101 Staffing Model by January 2012.

Task 14B: Refined Automated Spreadsheet based S101 Staffing Model

- Continue refining the system with user-feedback from TxDOT staff and provide quarterly updates.
- If requested, include models for estimating consultant volume.
- If requested, incorporate Texas State University consultant cost model.
- If requested, include TxDOT payout curves for construction projects to refine the CE staffing needs analysis by using the improved S-curve based cash flow forecast models.
- Submit refined S101 Staffing Model by August 2012.
- Provide training as needed so TxDOT can operate system in future.
- Provide documentation of assumptions, user guide, etc.

4.3 Basis of the PE Staffing Model

The basis for PE Staffing Estimation is the PE Hours model developed in Task 12. The model was developed from data provided by TxDOT on all projects that went to letting in Fiscal Years 2008–10, a total of 3172 CSJs. The model estimates PE Hours as a function of Project Construction Cost for each project type, based on a statistical analysis that found that PE Hours are correlated with project size and type/complexity.

For example, Figure 4.1 is a plot of the actual total PE Hours recorded on 134 Widen Non-Freeway projects in the dataset. Note that for the same construction cost, PE hours may vary by a factor greater than 5. While a trend of increasing hours with increasing construction cost is apparent, the scatter suggests that a linear relationship would be weak. However, when the data is plotted on logarithm scales in Figure 4.2, a clearer trend emerges.

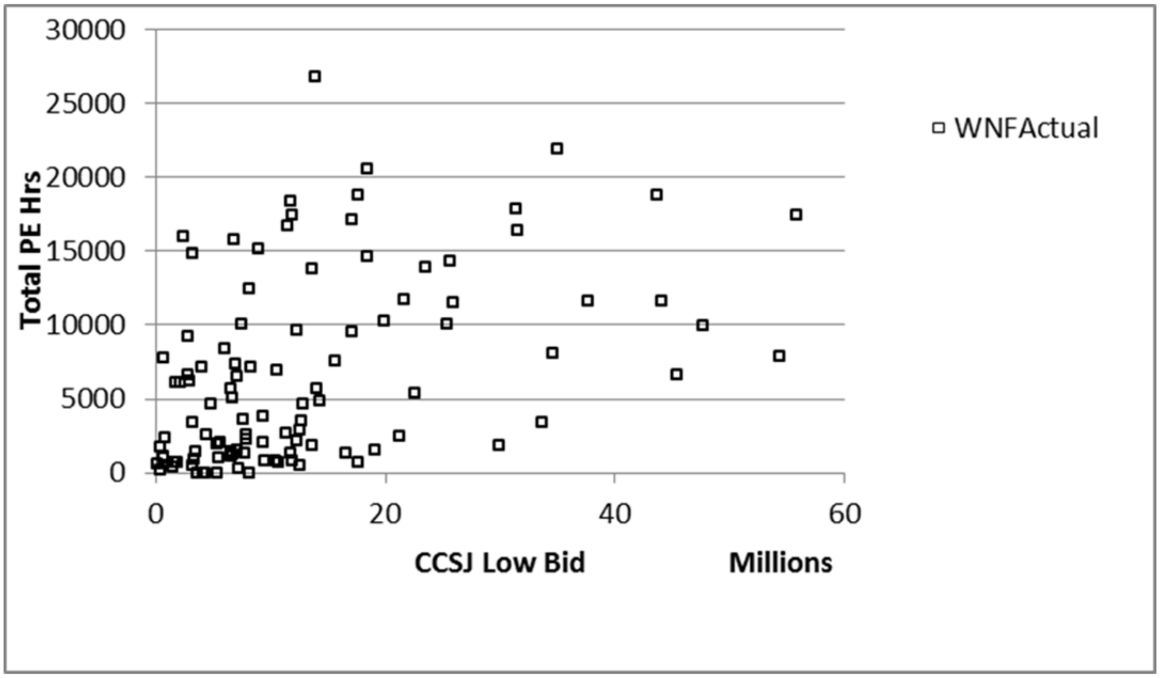


Figure 4.1: Actual Total PE Hours on 134 Widen Non-Freeway Projects in FY 08–10

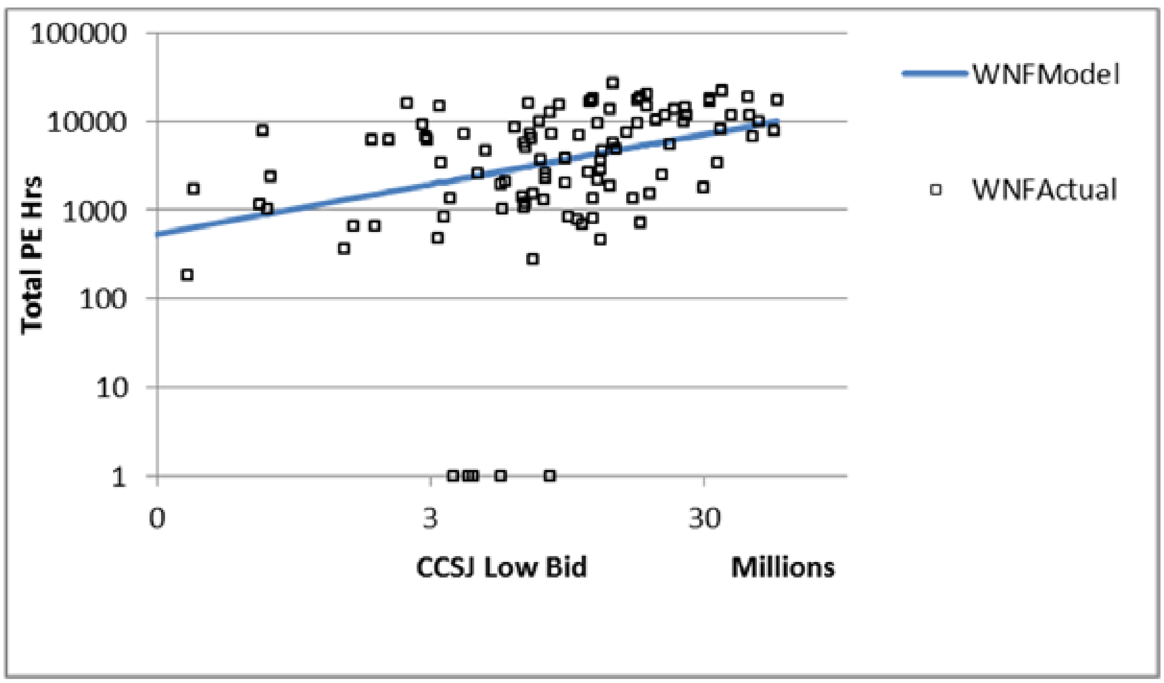


Figure 4.2: Fitted Line for PE Hours on WNF Projects in FY 08–10, Log-Log Plot

The statistically fitted line for the data is

Log (PE Hours) = - 0.3342 + 0.5594*LogConstrCost

By definition, the observations are Normally distributed around the regression line, and about half of them are above or below the line.

In non-log terms, the relationship is

PE Hours = 0.4632*ConstrCost$^{0.5594}$

As the output (construction cost or project size) increases, the level of input (PE hours) per unit output levels off, a phenomenon referred to as "economies of scale." Log relationships are common in production work. However, in engineering work there is variability in the effort required for each project, and construction cost is a crude measure of output, so the fitted model is expected to have a larger error than, say, a model for widgets produced in a factory. Figure 4.3 shows the fitted line for the data plotted on regular axes.

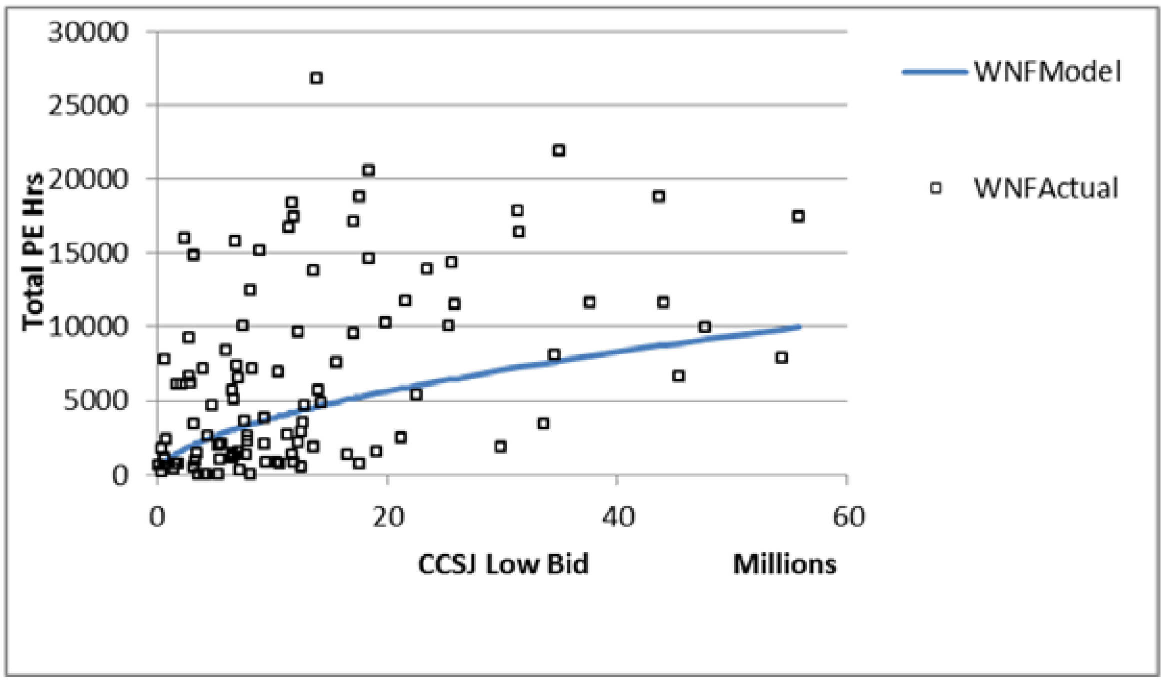


Figure 4.3: Fitted Model and Raw Data for WNF

Now it is seen that, even though the data is 'balanced' around the fitted line, the log transform resulted in the 'errors' (difference from the line) on the upper side being larger than those on the lower side. Thus, even though the model is the 'best guess' for any single project, in aggregate it tends to underestimate the total hours across all projects. The logarithm transform resulted in the fitted line being the 'geometric mean' of the data. The arithmetic mean is an appropriate estimate when dealing with an aggregate set of projects.

Figure 4.4 shows the fitted lines for all the project types studied. The lines are plotted only for the valid range of construction cost for each type. The uppermost line is for WF, Widen Freeway projects. Next down is WNF, Widen Non-Freeways, then BR, Bridge Replacements. The lowest is LSE, Landscape projects, then OV, Overlays. The project types not listed were found to be statistically similar, and assigned to the "Other" pool.

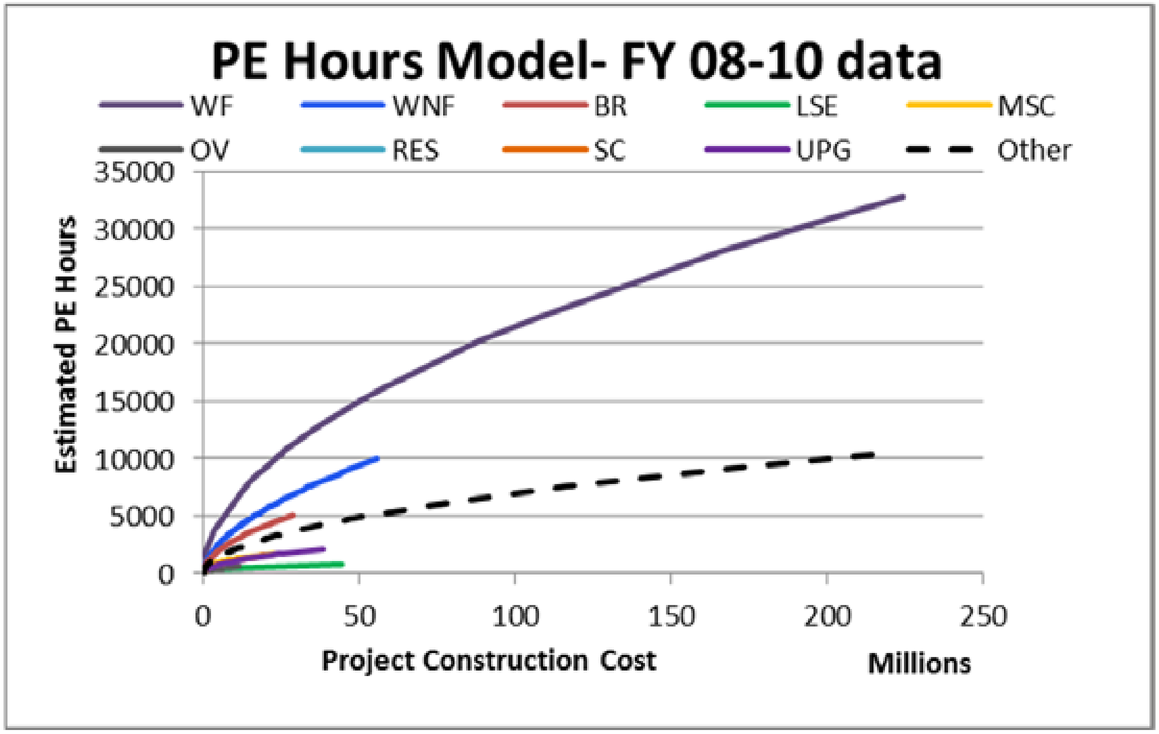


Figure 4.4: PE Hours Model Based on all CSJs Let in FY 08–10

CNF, INC, and NLF projects were too few to be modeled. In general, more complex project types require more hours, so it is recommended that the WF model be used for those. Similarly, the WNF model could be used for NNF. The "Other" model is applicable for BWR, RER, and less complex projects.

The model indicates that project complexity increases the need for PE hours, so it is likely that for a given project type, more complex work will require more hours. It is appropriate to establish some bounds on the estimate for each project type to provide estimators with a confidence range.

4.4 Confidence Intervals on PE Hours Estimates

For a given model of the form Y = A + B*x, the confidence interval for Y is

$$\mathbf{A + B{*}X \pm t\ {*}s}$$

Where **s** is the standard error (SE) for that specific model and **t** is the Student-t statistic for the number of observations. **s** is computed as

$$\mathbf{s = \sqrt{\{\sum(X-\ddot{X})^2\}} \,/\, (n-1)}$$

Where $\ddot{X}$ is the mean value of all X observations, **n** is the number of observations, and **t** is the appropriate **t**-statistic for the desired confidence interval. For **n** greater than 120, **t** goes to **Z** (the Normal-distribution statistic).

However, for a given X (that is, when you know the value of the independent variable for which you want to estimate Y), the confidence interval on the Y estimate is

$$\mathbf{Y = A + B{*}X \pm t * s * \sqrt{[\{(n+1)/n\} + \{(X-\ddot{X})^2/\sum(X-\ddot{X})^2\}]}}$$

Where **t** is the t-statistic for the desired 70% confidence interval, which depends on the value of **n** and the complexity of the model. The confidence interval widens as you go away from the mean X value due to greater uncertainty in the estimate further away from the mean. That widening factor is provided in the spreadsheet calculator. Figure 4.5 illustrates the case for RER projects.

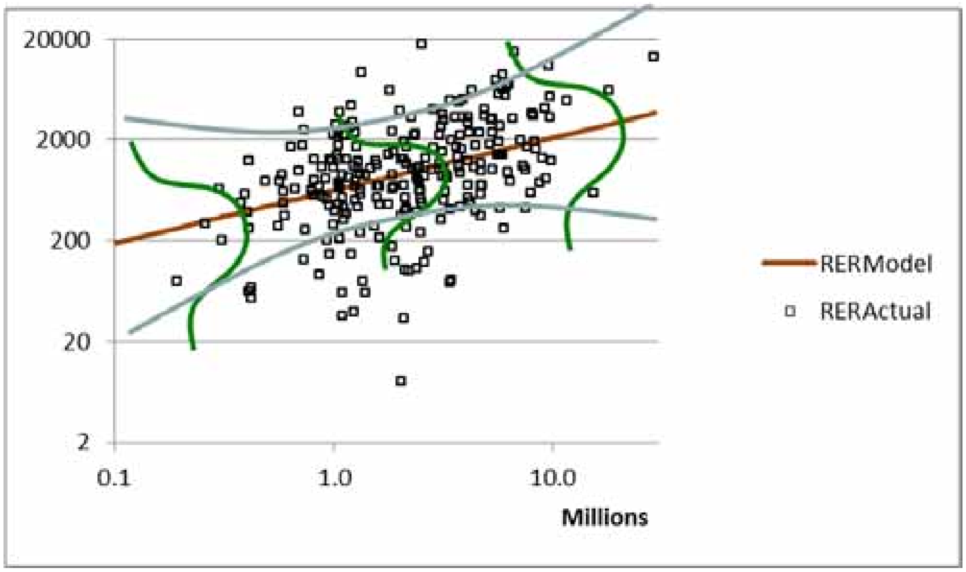


Figure 4.5: Widening of Confidence Interval Away from Mean

The following example illustrates how the 70% confidence range is determined. Figure 4.6 is the model for Widen Freeway projects. The median line is

Log (PE Hours) = 0.1549+ 0.5223*LogConstrCost

To obtain the upper and lower 70% limits, an amount equal to $\mathbf{t * s * \sqrt{[\{(n+1)/n\} + \{(X-\ddot{X})^2/\sum(X-\ddot{X})^2\}]}}$ is added to or subtracted from the median estimate. The t value used is that for 35% coverage on each side of the mean (total 70% coverage), and depends on the degrees of freedom computed from n. The upper and low bounds are also shown in Figure 4.6.

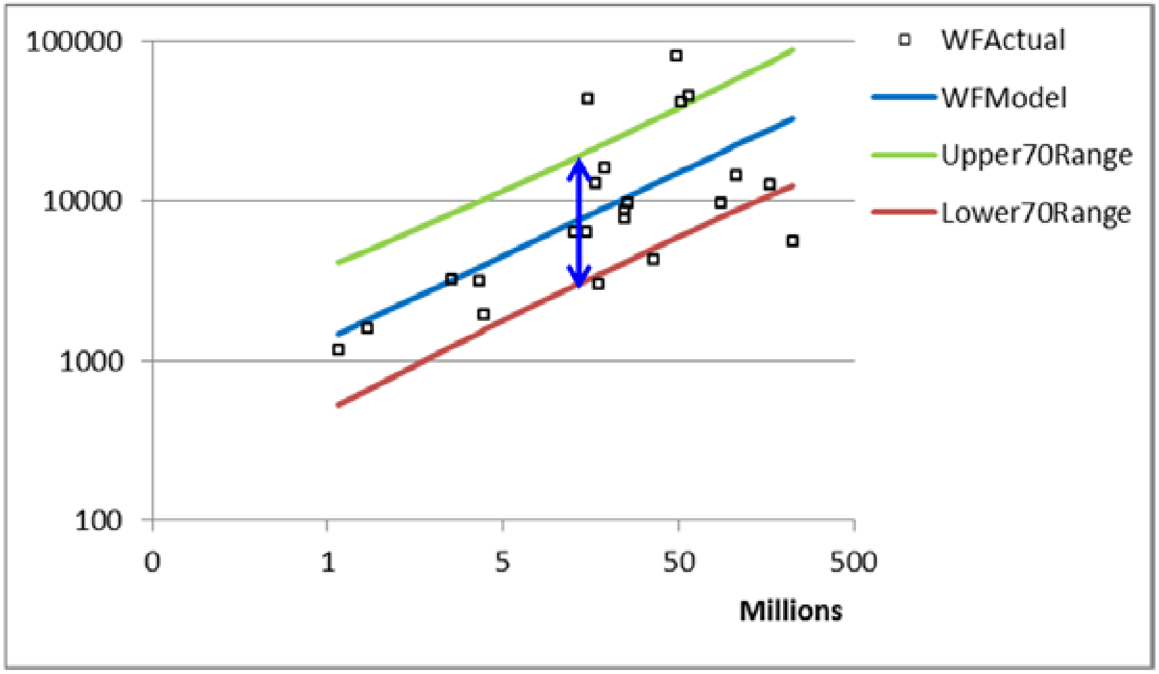


Figure 4.6: PE Hours Model for WF Projects with Upper and Lower 70% Range: Log-Log Plot

Even though the bounds appear parallel to the median line, there is a small but significant widening away from the mean. After normalization to convert the factor to a multiplier/divider, the variation is illustrated in Figure 4.7. The factor varies from 2.5181 near mean project cost to 2.7797 at extremes of cost.

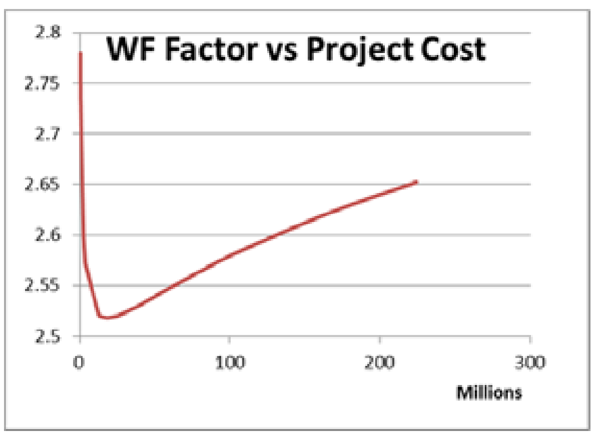


Figure 4.7: Change in Widening Factor for WF Projects Across Cost Range

The resulting normalized curves are illustrated in Figure 4.8. It is seen that the upper line is further from the mean than the lower line, the consequence of using the log transform and fitting the geometric mean as the best estimate. The arithmetic mean of the upper and lower estimates is also shown.

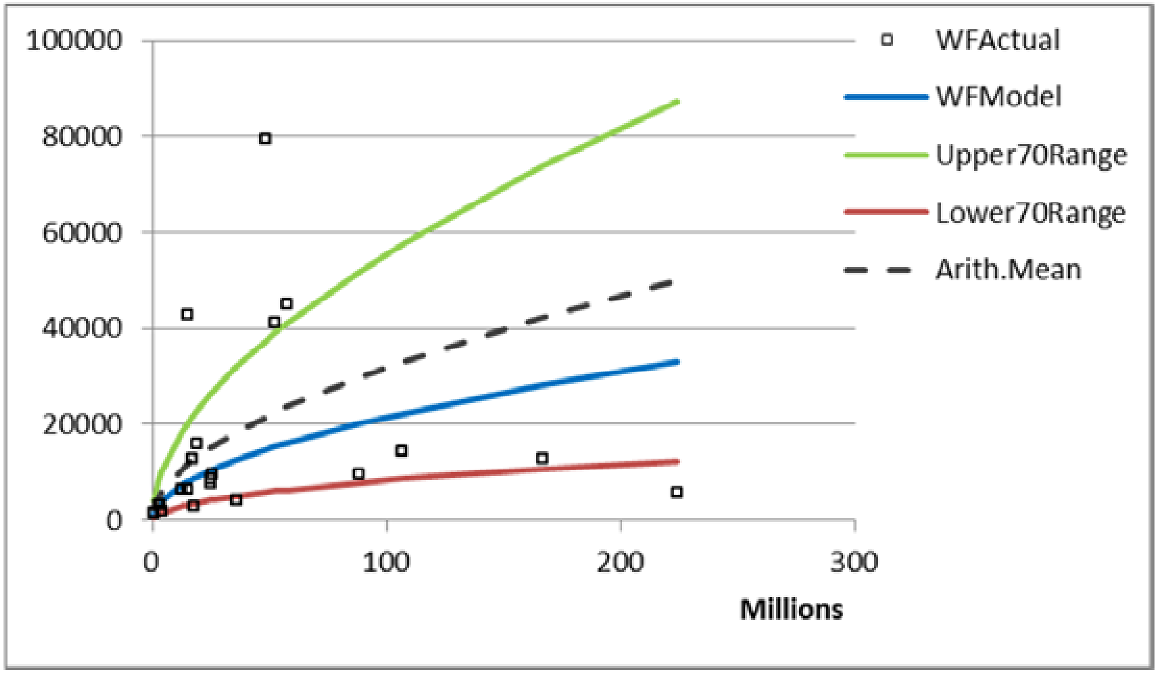


Figure 4.8: PE Hours Model for WF Projects with Upper and Lower 70% Range

For example, for a \$18.7 m project (the median project size in the dataset), the 70% confidence range for PE Hours is 22,592–3563; the arithmetic mean is 13,077 hours compared to median value of 8972 hours. The following sections and series of figures illustrate the same information for each project type.

4.4.1 70% Confidence Range for BR projects

The model for BR projects is

Log (PE Hours) = -0.1941+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 2.3434 near mean project cost to 2.3846 at extremes of cost (see spreadsheet).

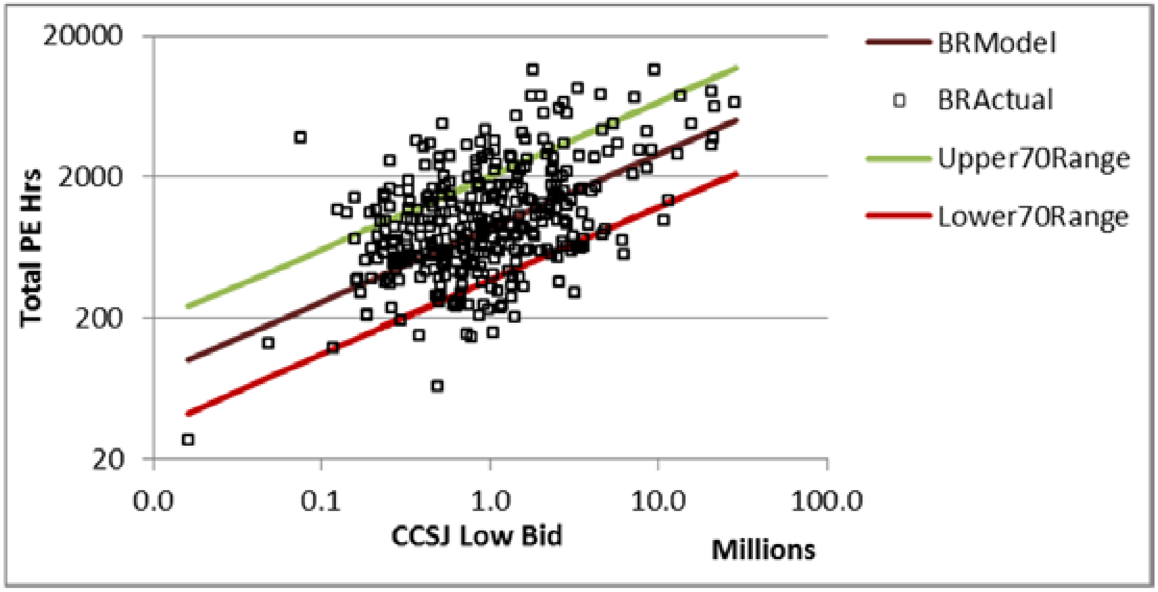


Figure 4.9: PE Hours Model for BR Projects with Upper and Lower 70% Range: Log-Log Plot

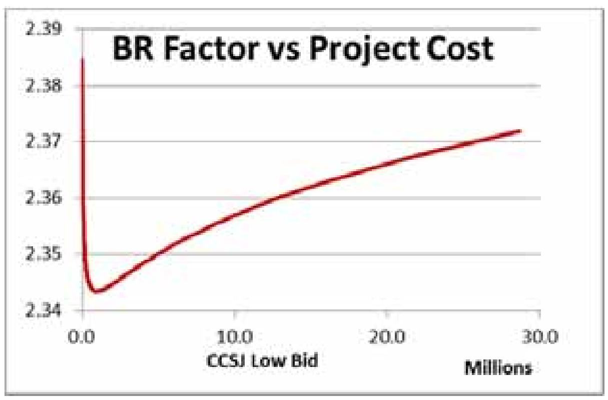


Figure 4.10: Change in Widening Factor for BR Projects Across Cost Range

4.4.2 70% Confidence Range for BWR projects

The model for BWR projects is

Log (PE Hours) = -0.3342+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.3016 near mean project cost to 3.4067 at extremes of cost (see spreadsheet).

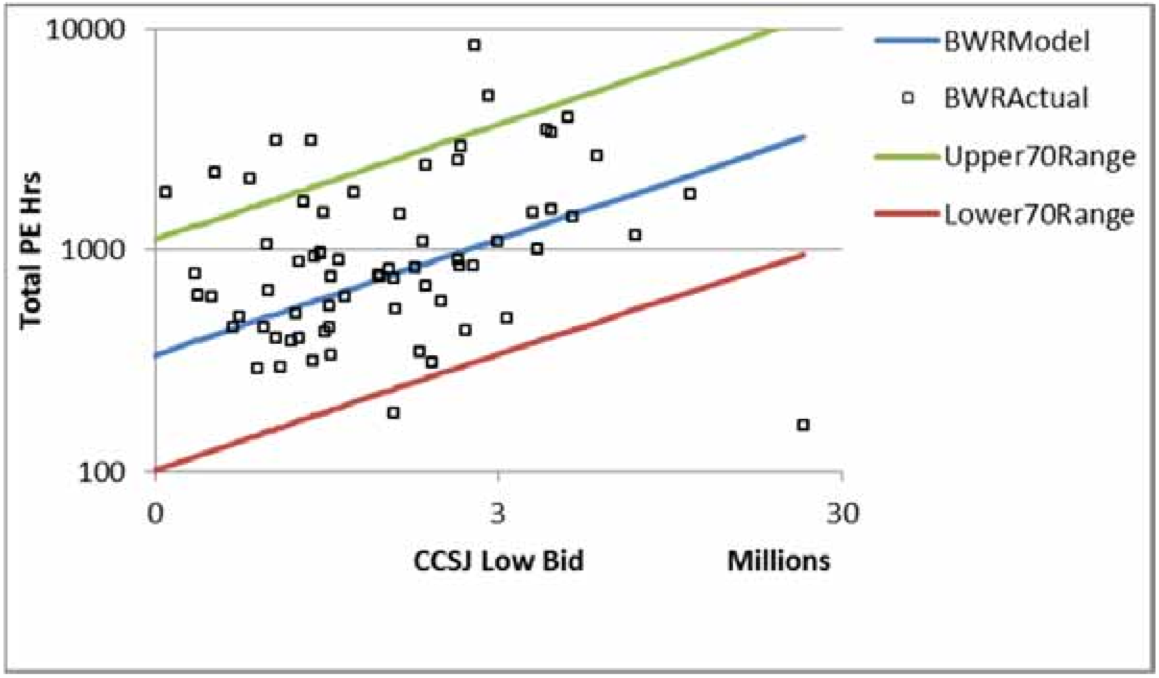


Figure 4.11: PE Hours Model for BWR Projects with Upper and Lower 70% Range: Log-Log Plot

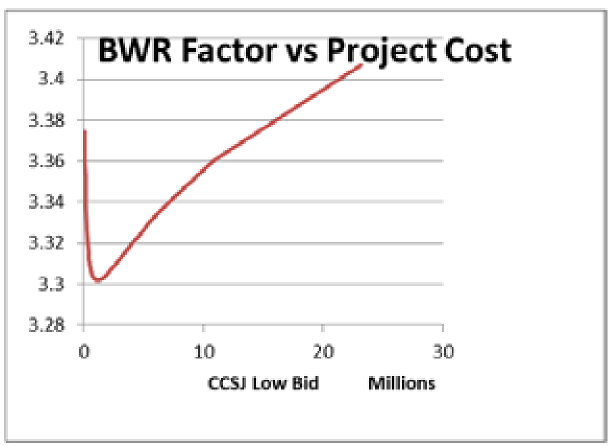


Figure 4.12: Change in Widening Factor for BWR Projects Across Cost Range

4.4.3 70% Confidence Range for CNF projects

The model for CNF projects is questionable. Note the poor fit in Figure 4.13 due to just 5 data points. It is recommended that the WF model (overlaid) be used instead (see WF model).

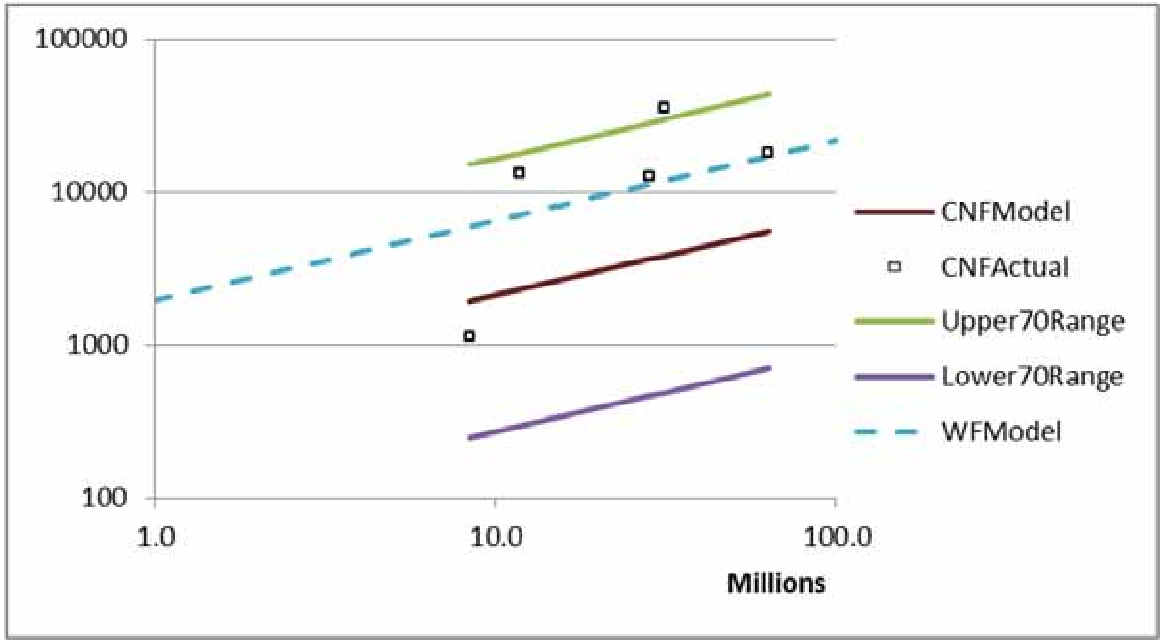


Figure 4.13: PE Hours Model for WF Projects with Upper and Lower 70% Range: Log-Log Plot

4.4.4 70% Confidence Range for INC projects

The model for INC projects is questionable. Note the poor fit and unbalanced residuals in Figure 4.14. It is recommended that the WF model (overlaid) be used instead (see WF model).

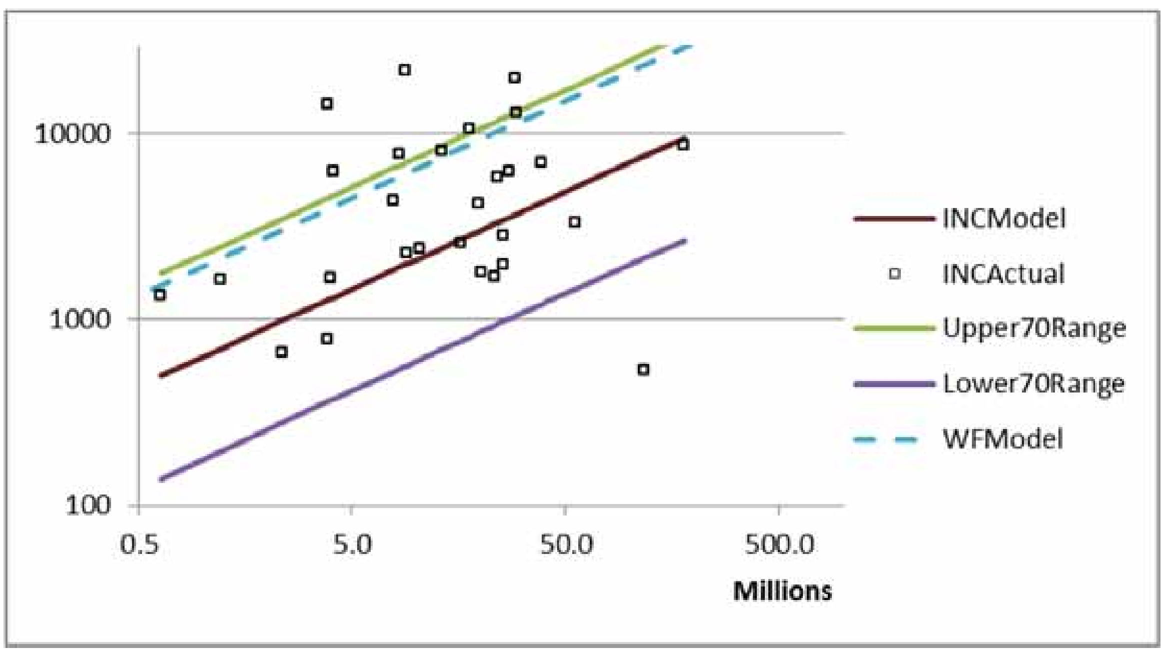


Figure 4.14: PE Hours Model for INC Projects with Upper and Lower 70% Range: Log-Log Plot

4.4.5 70% Confidence Range for LSE projects

The model for LSE projects is

Log (PE Hours) = 1.0343+ 0.2432*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 2.2124 near mean project cost to 4.0760 at extremes of cost (see spreadsheet).

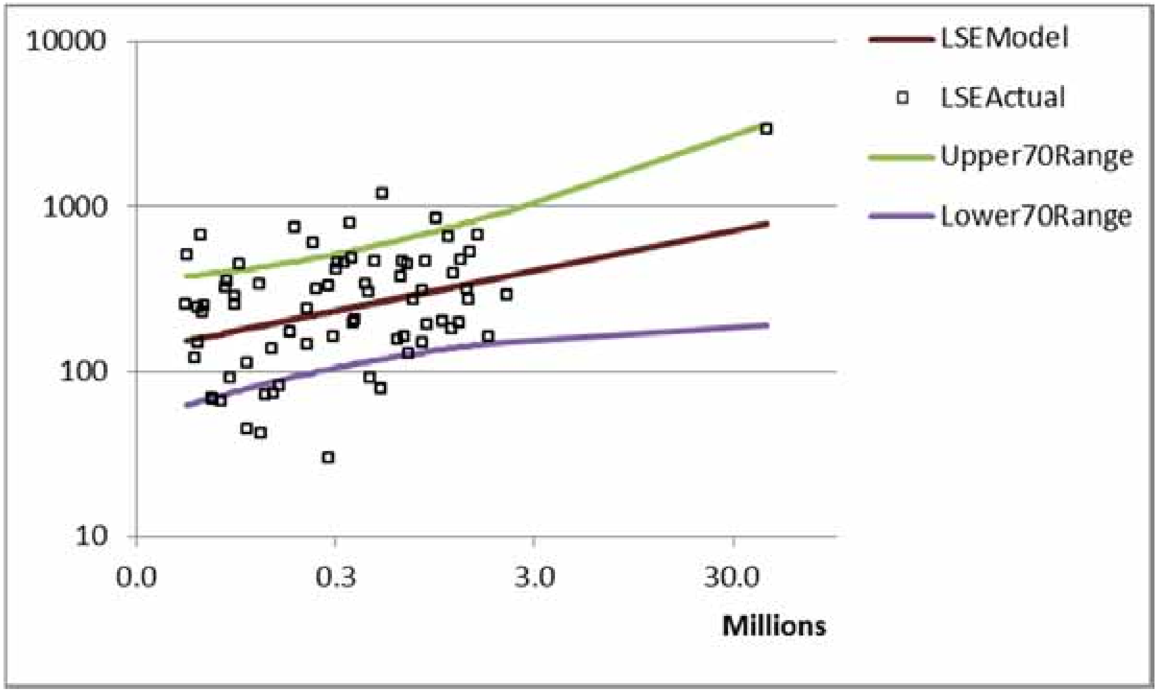


Figure 4.15: PE Hours Model for LSE Projects with Upper and Lower 70% Range: Log-Log Plot

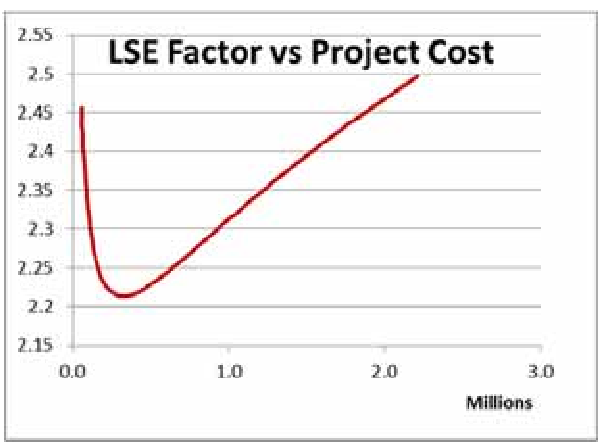


Figure 4.16: Change in Widening Factor for LSE Projects Across Cost Range

4.4.6 70% Confidence Range for MSC projects

The model for MSC projects is

Log (PE Hours) = -0.3342+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.5048 near mean project cost to 3.5492 at extremes of cost (see spreadsheet).

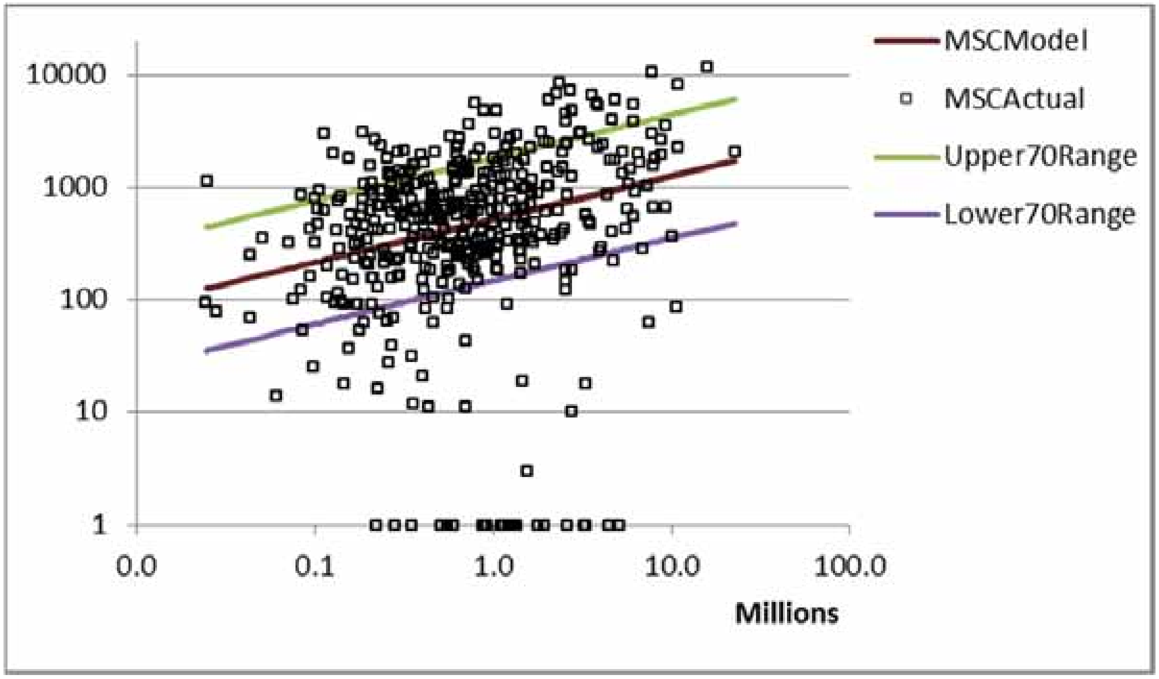


Figure 4.17: PE Hours Model for MSC Projects with Upper and Lower 70% Range: Log-Log Plot

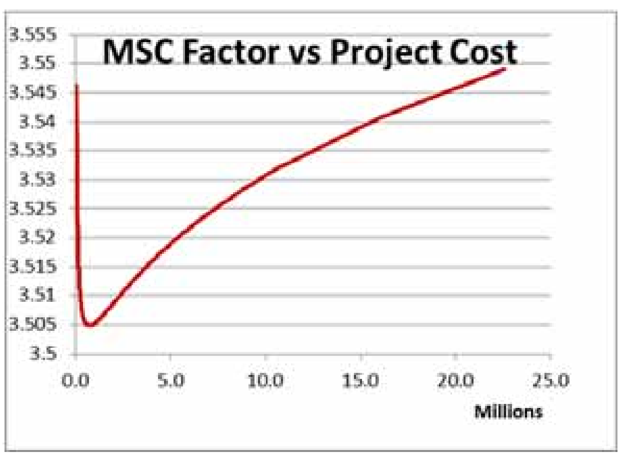


Figure 4.18: Change in Widening Factor for MSC Projects Across Cost Range

4.4.7 70% Conf. Range for NLF projects

The model for NLF projects is questionable. Note the poor fit due to just 5 data points. It is recommended that the WF model (overlaid) be used instead (see WF model).

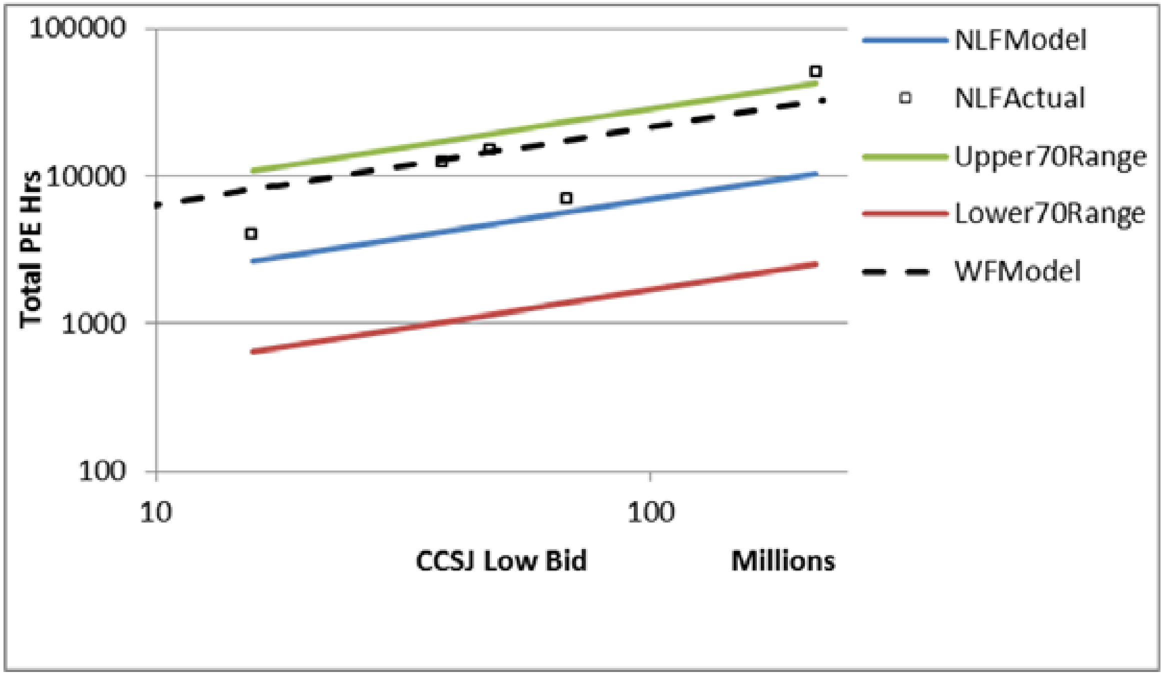


Figure 4.19: PE Hours Model for NLF Projects with Upper and Lower 70% Range: Log-Log Plot

4.4.8 70% Confidence Range for NNF projects

The model for NNF projects is questionable. Note the unbalanced residuals. It is recommended that the WNF model (overlaid) be used instead (see WNF model).

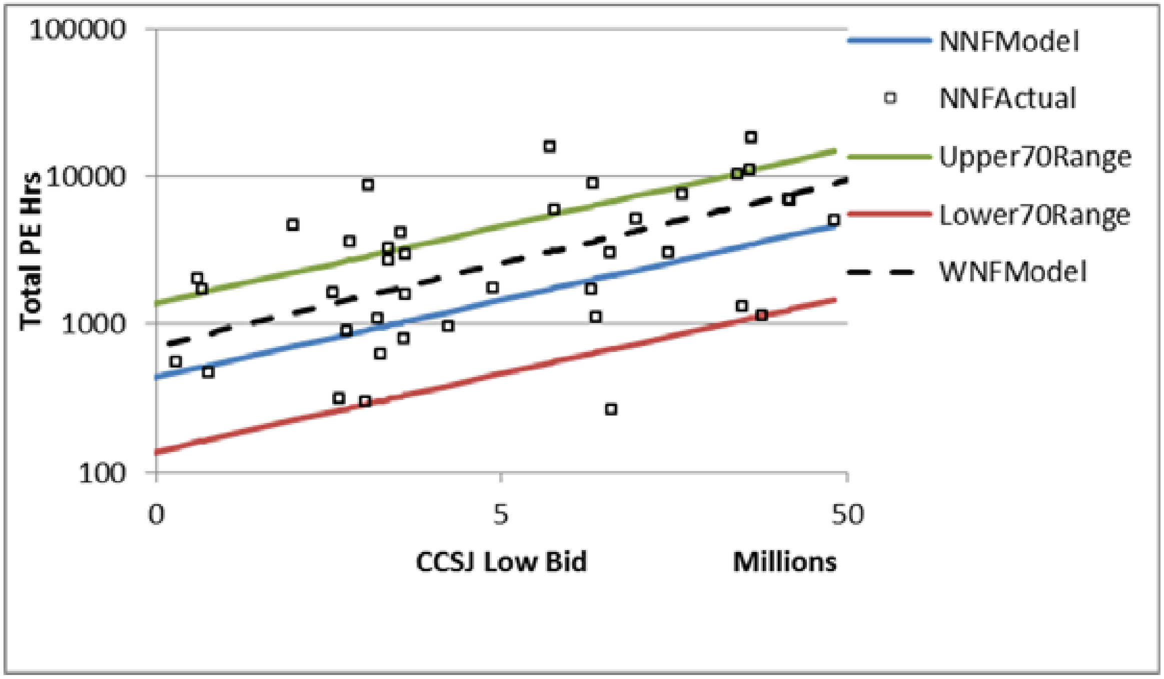


Figure 4.20: PE Hours Model for NNF Projects with Upper and Lower 70% Range: Log-Log Plot

4.4.9 70% Confidence Range for OV projects

The model for OV projects is

Log (PE Hours) = -0.3342+ 0.4420*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.3102 near mean project cost to 3.3549 at extremes of cost (see spreadsheet).

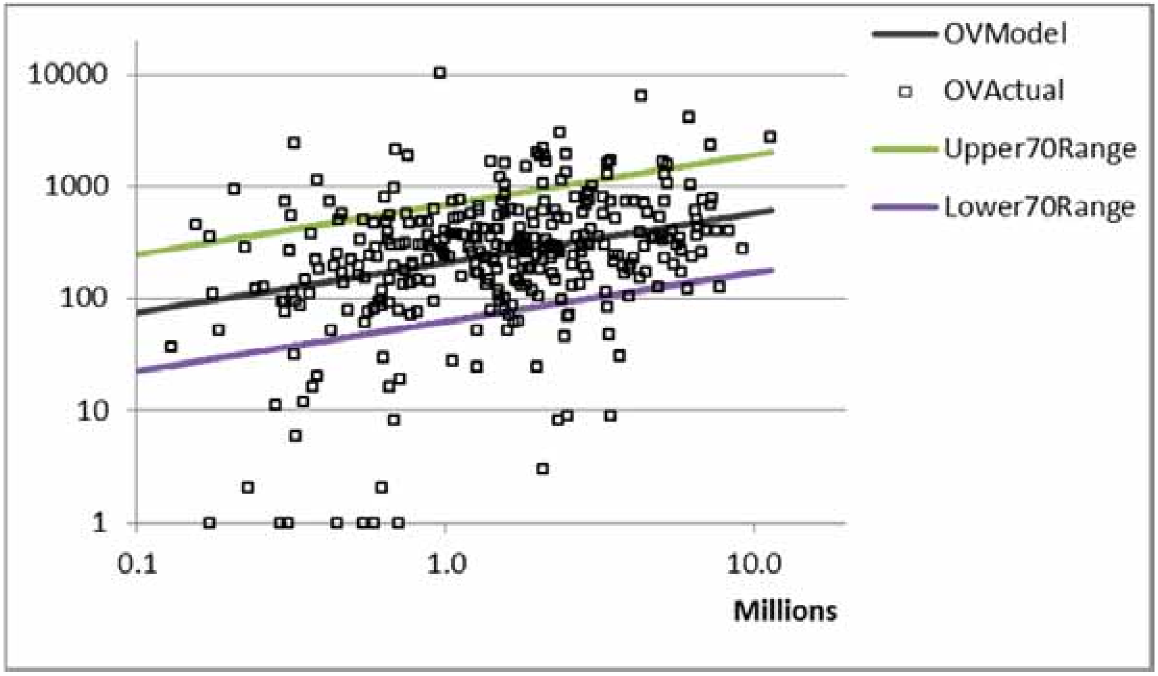


Figure 4.21: PE Hours Model for OV Projects with Upper and Lower 70% Range: Log-Log Plot

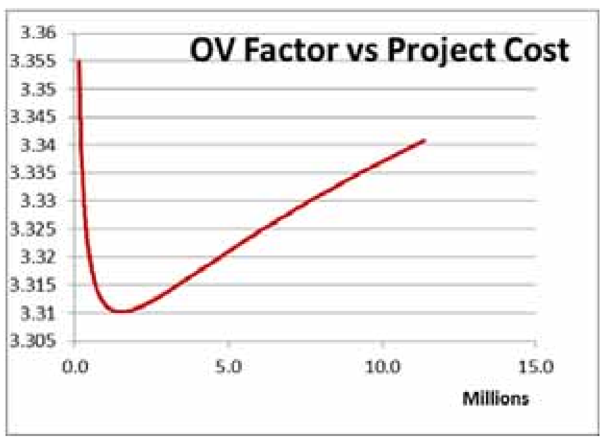


Figure 4.22: Change in Widening Factor for OV Projects Across Cost Range

4.4.10 70% Confidence Range for RER projects

The model for RER projects is

Log (PE Hours) = -0.3342+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.1481 near mean project cost to 3.1774 at extremes of cost (see spreadsheet)

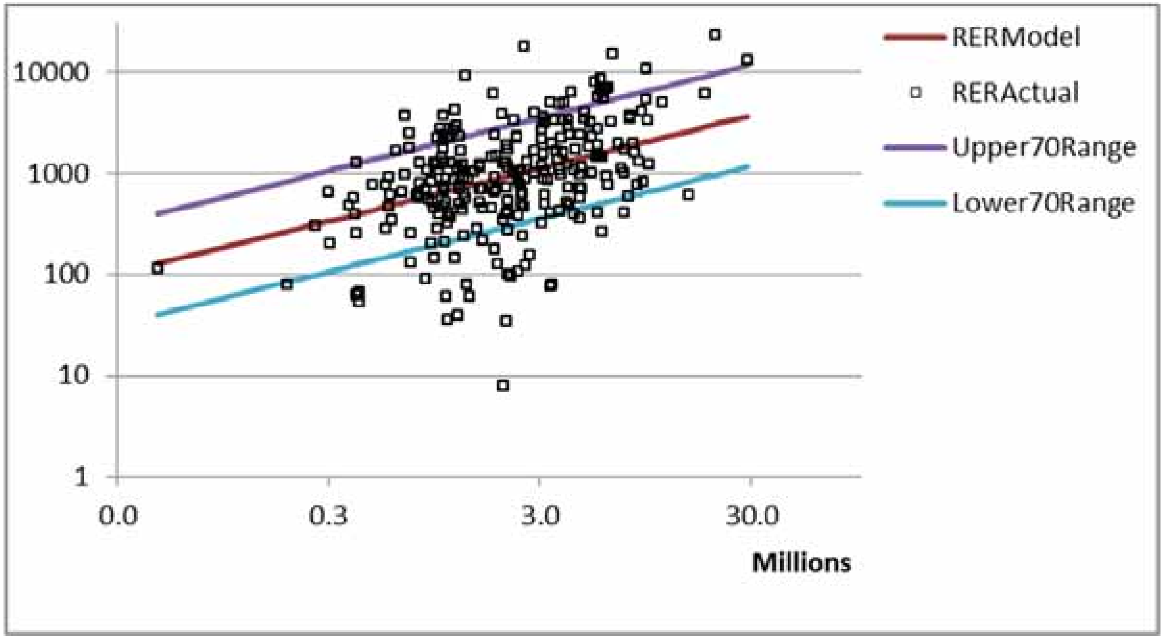


Figure 4.23: PE Hours Model for RER Projects with Upper and Lower 70% Range: Log-Log Plot

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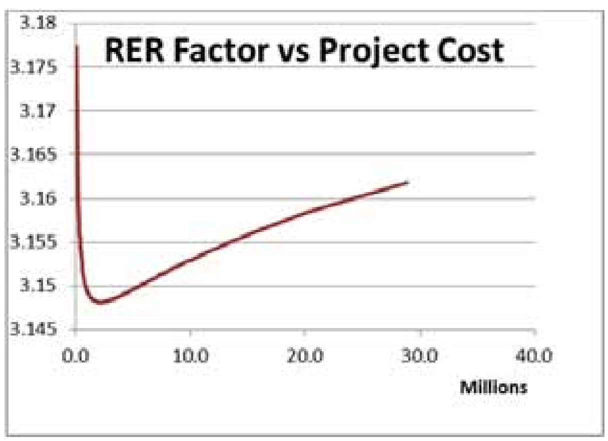

Figure 4.24: Change in Widening Factor for RER Projects Across Cost Range

4.4.11 70% Confidence Range for RES projects

The model for RES projects is

Log (PE Hours) = -0.3342+ 0.4841*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 2.5938 near mean project cost to 2.7639 at extremes of cost (see spreadsheet).

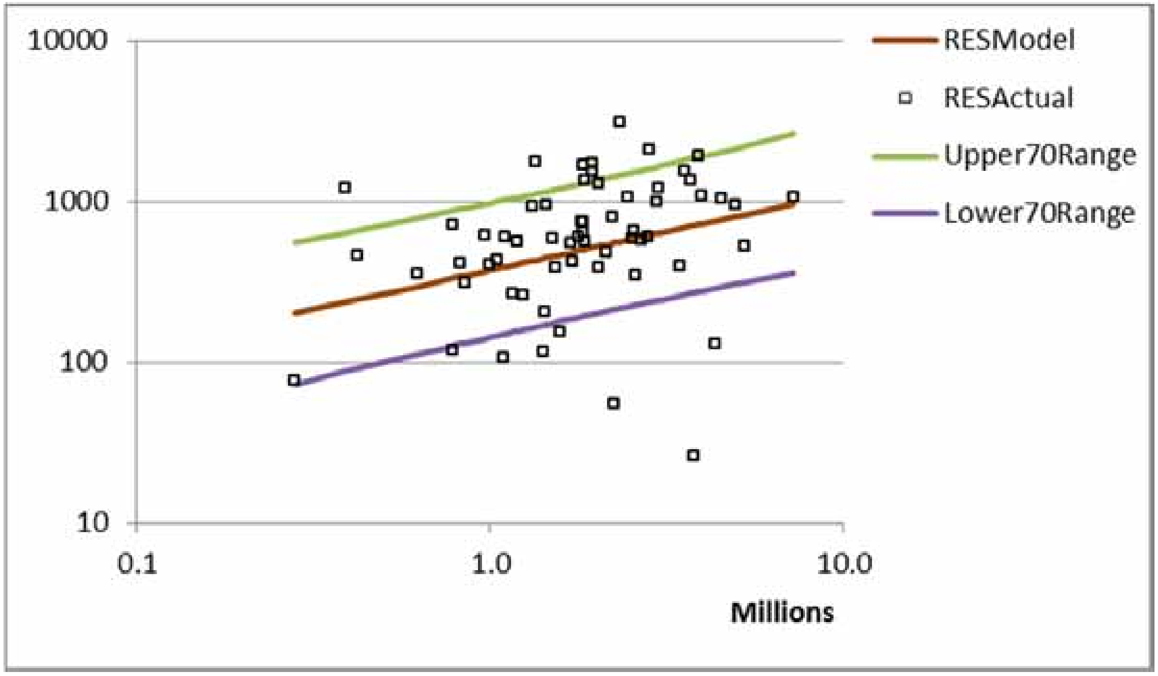

Figure 4.25: PE Hours Model for RES Projects with Upper and Lower 70% Range: Log-Log Plot

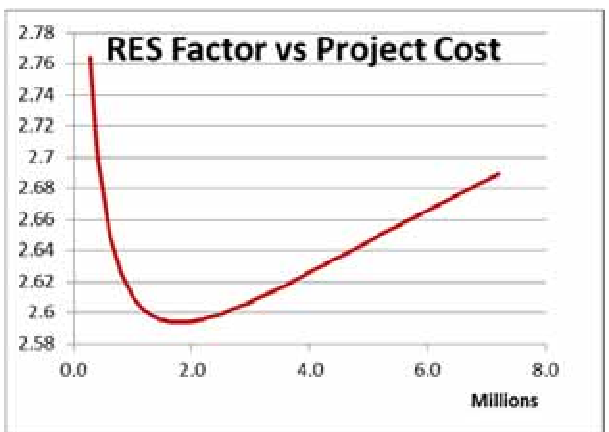

Figure 4.26: Change in Widening Factor for RES Projects Across Cost Range

4.4.12 70% Confidence Range for SC projects

The model for SC projects is

Log (PE Hours) = -0.6056+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.5244 near mean project cost to 3.7634 at extremes of cost (see spreadsheet).

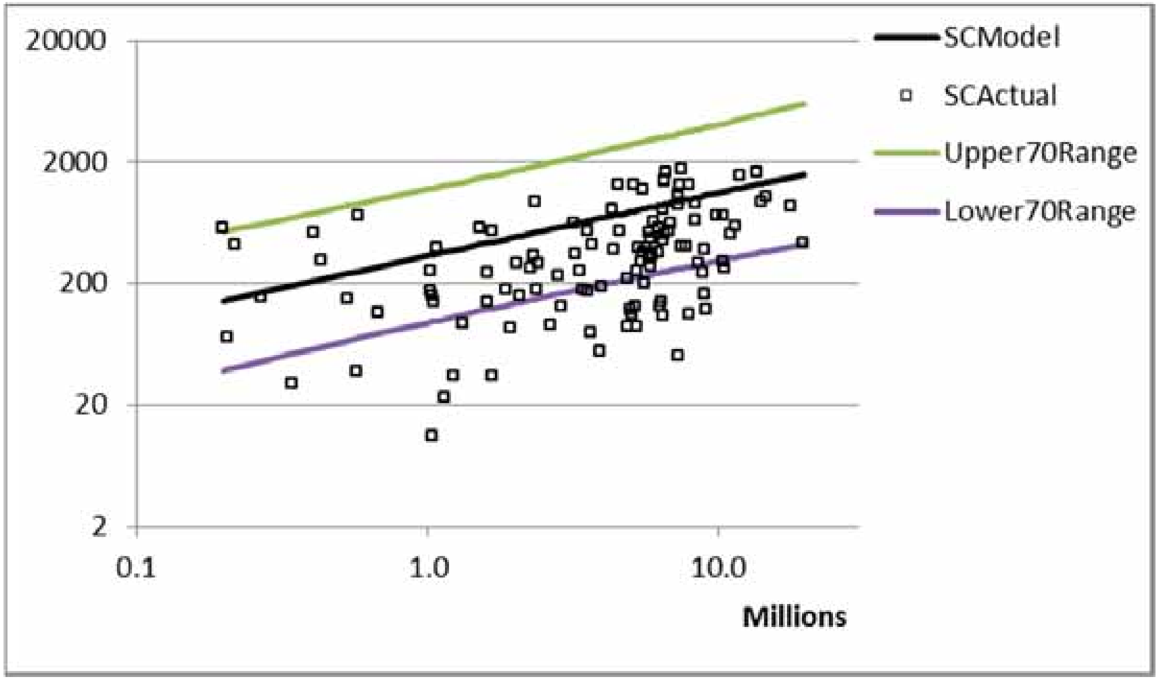

Figure 4.27: PE Hours Model for SC Projects with Upper and Lower 70% Range: Log-Log Plot

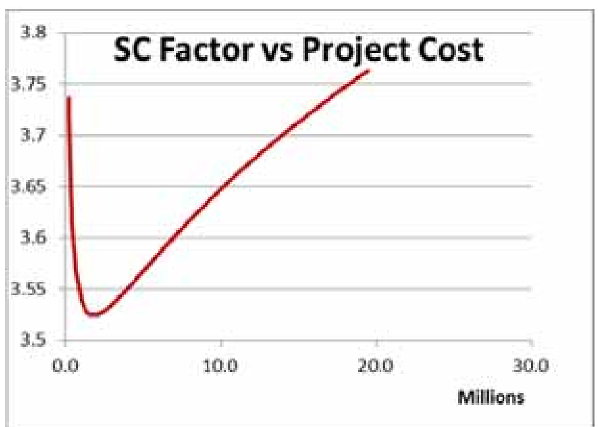

Figure 4.28: Change in Widening Factor for SC Projects Across Cost Range

4.4.13 70% Confidence Range for SFT projects

The model for SFT projects is

Log (PE Hours) = -0.3342+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 2.4971 near mean project cost to 2.5253 at extremes of cost (see spreadsheet).

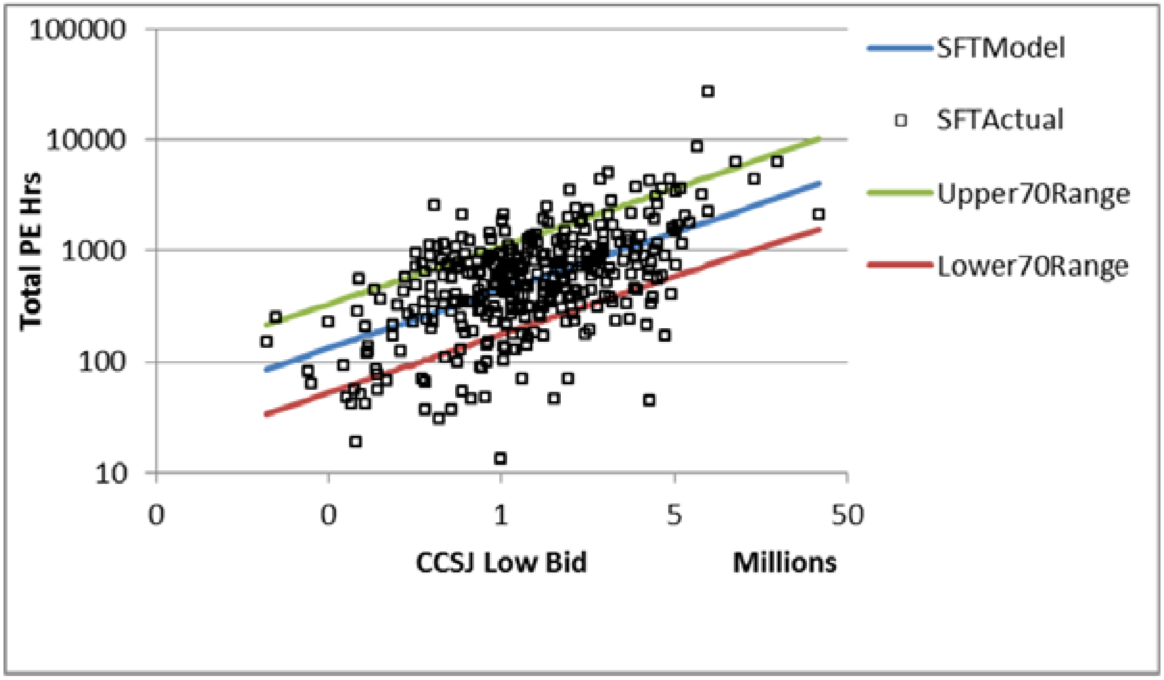

Figure 4.29: PE Hours Model for SFT Projects with Upper and Lower 70% Range: Log-Log Plot

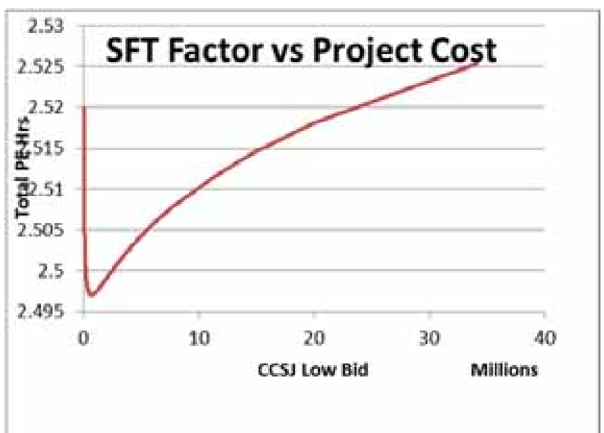

Figure 4.30: Change in Widening Factor for SFT Projects Across Cost Range

4.4.14 70% Confidence Range for TS projects

The model for TS projects is

Log (PE Hours) = -0.3342+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.1462 near mean project cost to 3.2411 at extremes of cost (see spreadsheet).

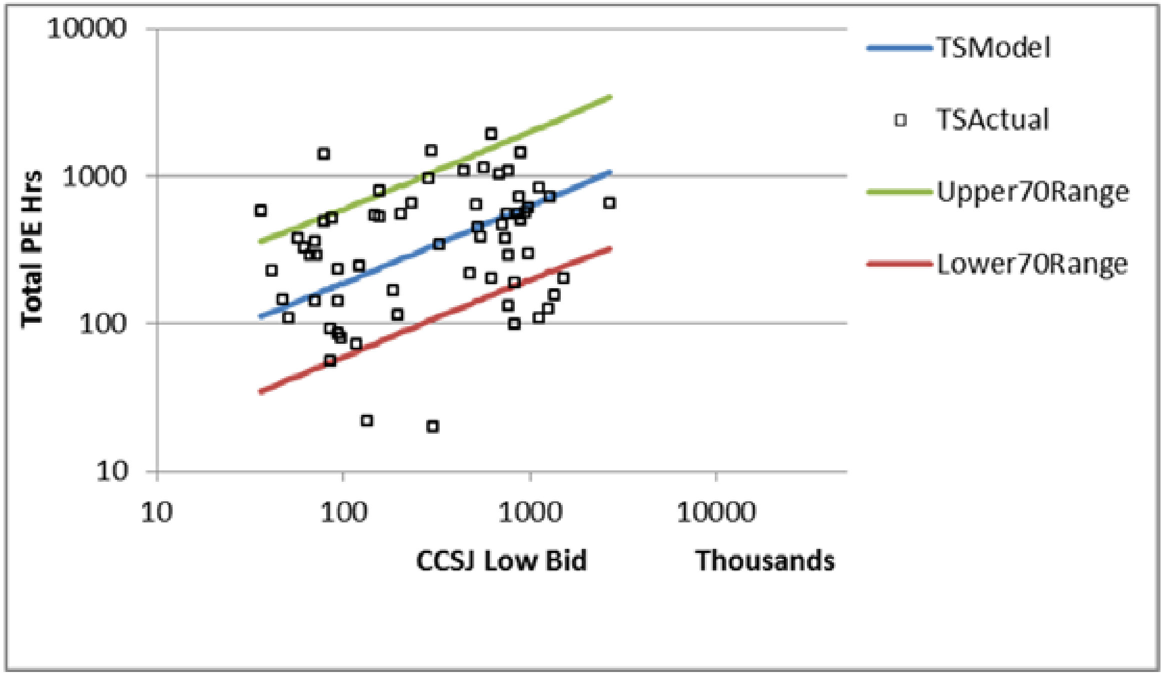

Figure 4.31: PE Hours Model for TS Projects with Upper and Lower 70% Range: Log-Log Plot

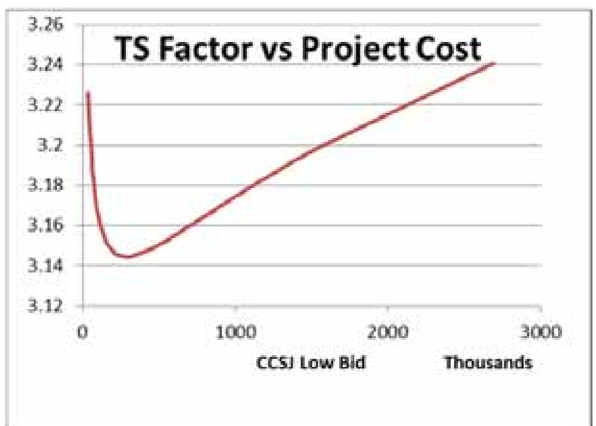

Figure 4.32: Change in Widening Factor for TS Projects Across Cost Range

4.4.15 70% Confidence Range for UGN projects

The model for UGN projects is

Log (PE Hours) = -0.3342+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.9689 near mean project cost to 4.1805 at extremes of cost (see spreadsheet).

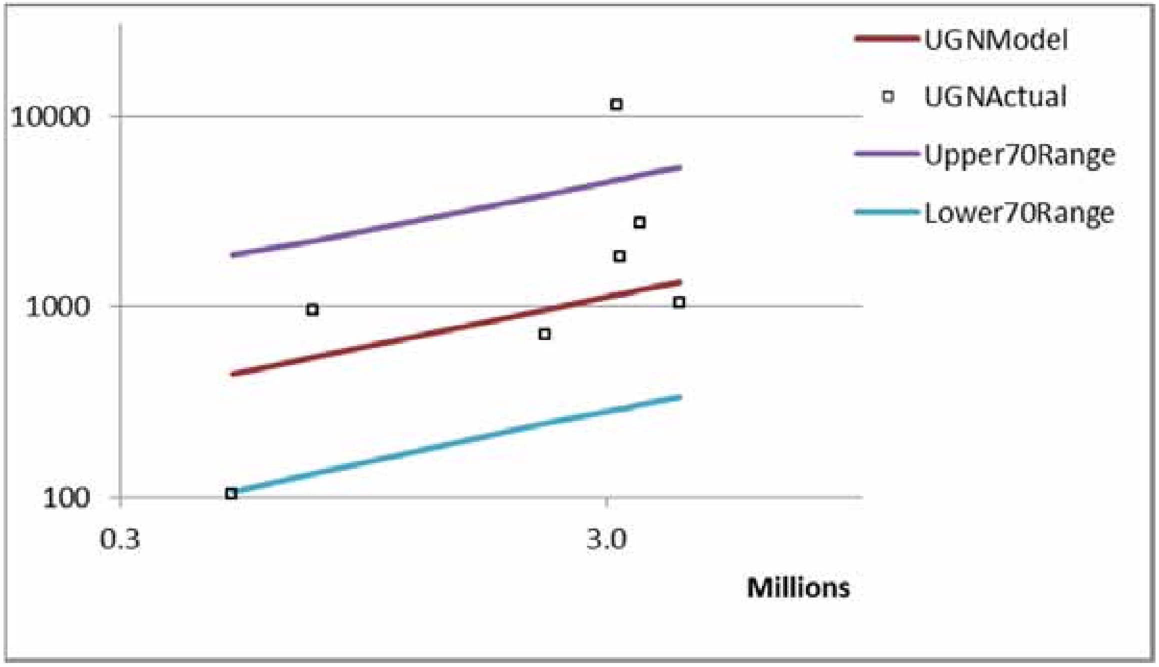

Figure 4.33: PE Hours Model for UGN Projects with Upper and Lower 70% Range: Log-Log Plot

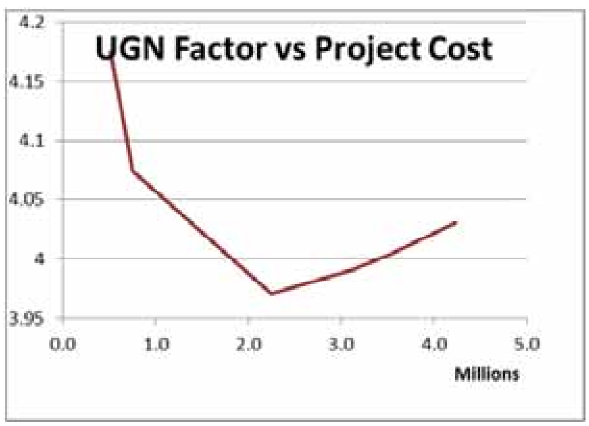

Figure 4.34: Change in Widening Factor for UGN Projects Across Cost Range

4.4.16 70% Confidence Range for UPG projects

The model for UPG projects is

Log (PE Hours) = -0.6277+ 0.5223*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.3668 near mean project cost to 3.4292 at extremes of cost (see spreadsheet).

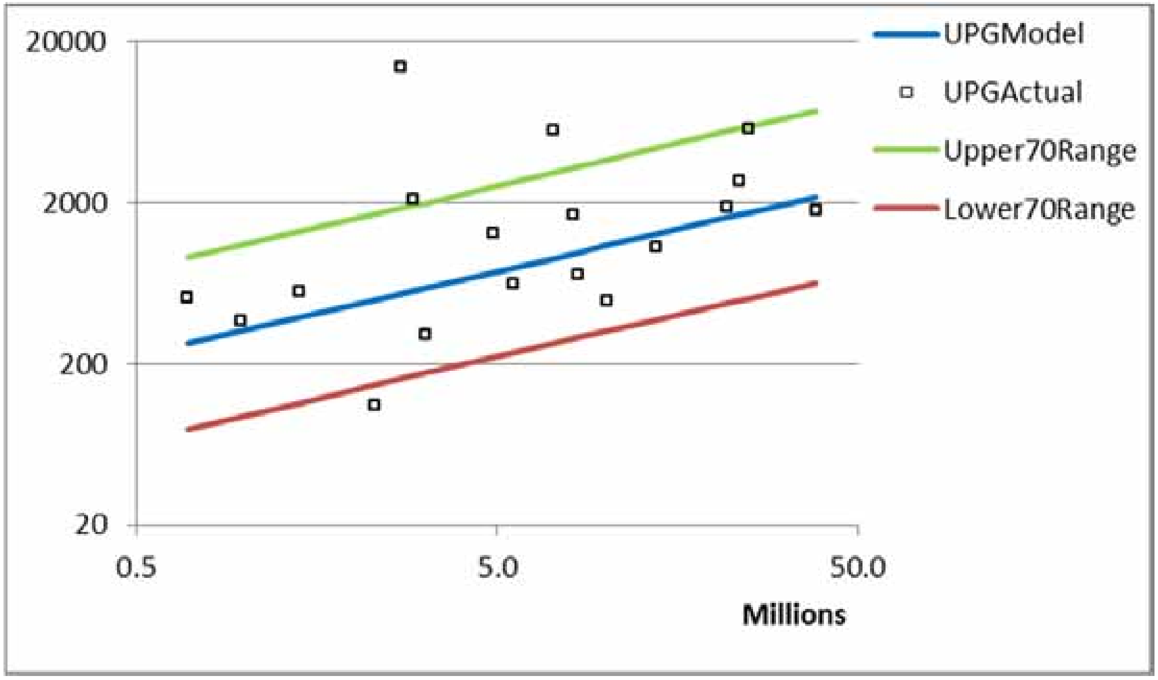

Figure 4.35: PE Hours Model for UPG Projects with Upper and Lower 70% Range: Log-Log Plot

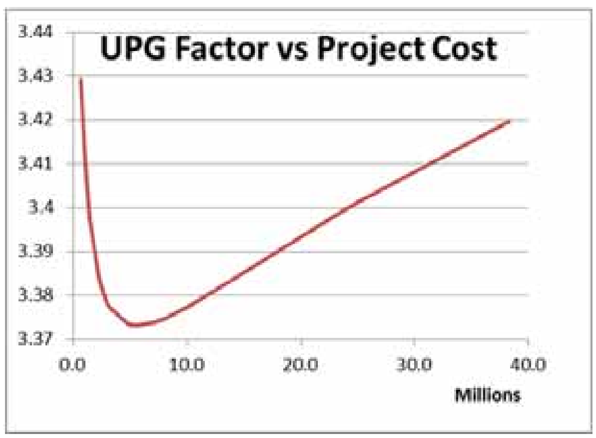

Figure 4.36: Change in Widening Factor for UPG Projects Across Cost Range

4.4.17 70% Confidence Range for WF projects

The model for WF projects is

Log (PE Hours) = 0.1549+ 0.5223*LogConstrCost

It is recommended that this model be used for CNF, INC and NLF projects as well. To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 2.5181 near mean project cost to 2.7797 at extremes of cost (see spreadsheet).

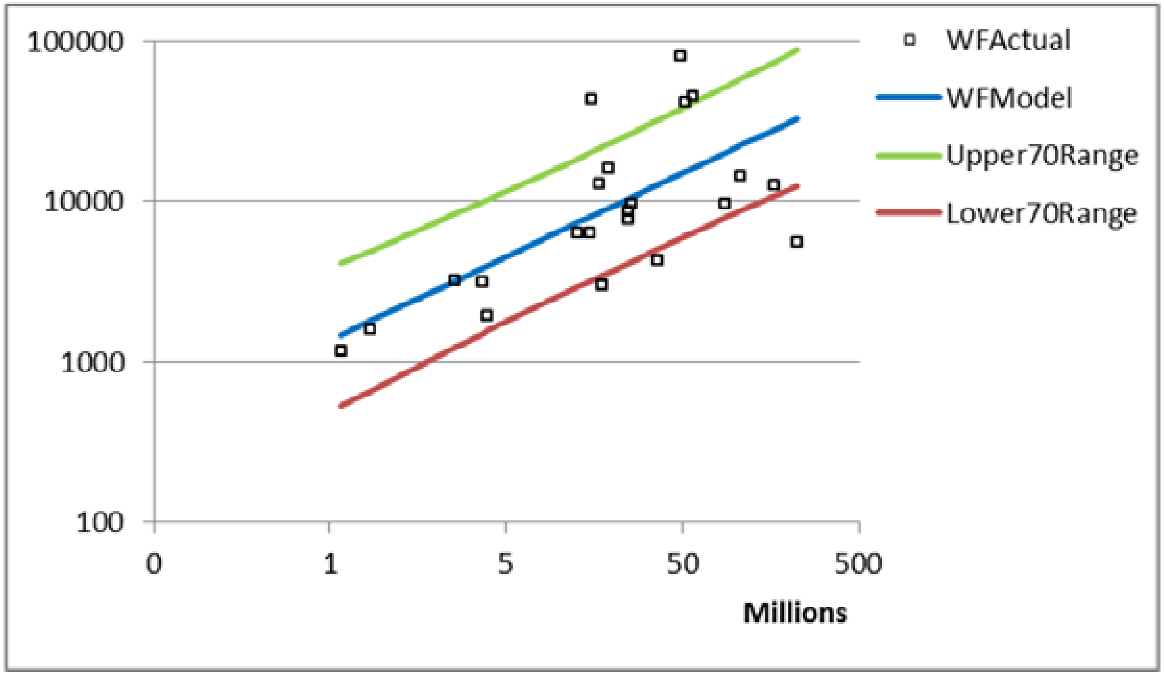

Figure 4.37: PE Hours Model for WF Projects with Upper and Lower 70% Range: Log-Log Plot

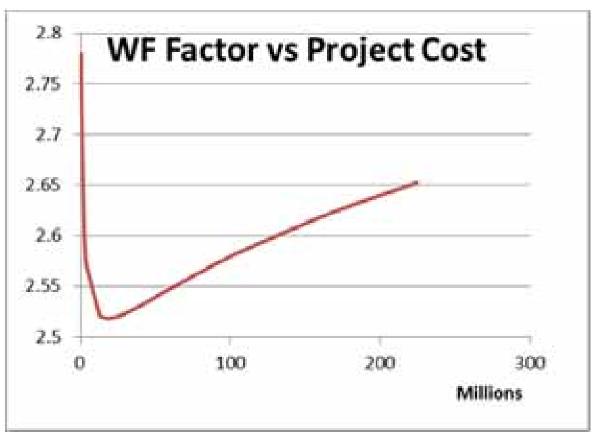

Figure 4.38: Change in Widening Factor for WF Projects Across Cost Range

4.4.18 70% Confidence Range for WNF projects

The model for WNF projects is

Log (PE Hours) = -0.3342+ 0.5594*LogConstrCost

To obtain upper and lower limits, multiply or divide estimate by a factor. Factor varies from 3.0229 near mean project cost to 3.0699 at extremes of cost (see spreadsheet).

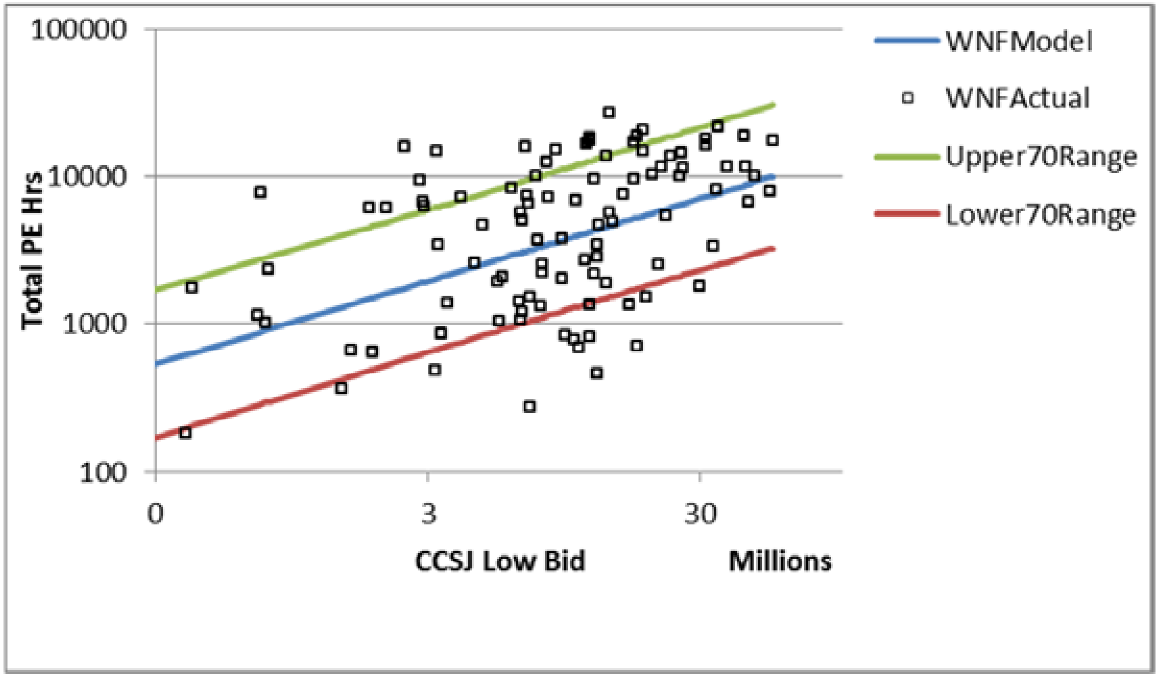

Figure 4.39: PE Hours Model for WNF Projects with Upper and Lower 70% Range: Log-Log Plot

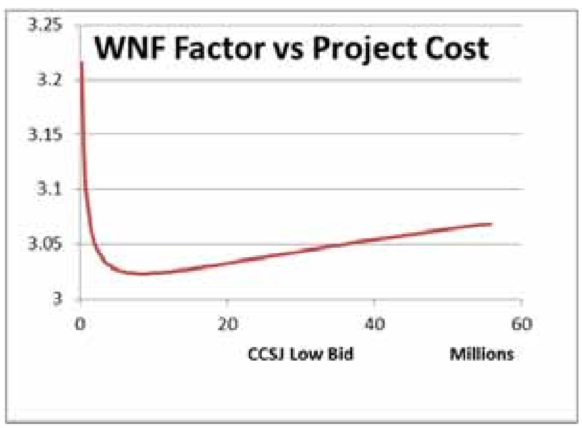

Figure 4.40: Change in Widening Factor for WNF Projects Across Cost Range

4.5 Conclusion

The PE Hours Model was developed for estimating program staffing. The Adjusted R^2 of the model is low, but at the aggregate level the effect of those errors tend to cancel. However, at the individual project level, the effect of the model standard error is large. In this report, the 70% confidence intervals for estimated PE Hours for each project type were presented. It is recommended that calculation at the individual project level take into account the arithmetic mean compared to the log (geometric) mean. These results were also submitted in a Microsoft Excel spreadsheet for easy calculation of mean, upper and lower 70-percentile staffing hours estimates for each project type.