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Final Report on Monitoring and Evaluation of SH-130 Project Construction

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Products

This report includes findings **to date** for two product deliverables. The attached CD includes Product Deliverable No.6 (Lessons Learned System). Chapter 4 includes an overview of the system while the system's user manual is provided in Appendix B. The system has been populated with lessons collected to date. Chapter 3 and Appendix A include preliminary analysis of benchmarking data as a follow-up to Product No.5.

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1. Introduction and Summary of Previous Reports

1.1 Introduction

This is the Final Report for TxDOT Study 0-4661. This report provides an overview of the activities accomplished as a part of this study. Included in this overview are brief descriptions of each of the research products generated (as presented below in this chapter), and a description of three efforts that were ongoing at the time that this study was terminated by TxDOT:

- Procurement Change Implementation Framework (Chapter Two in this report)
- Project Performance Benchmarking (Chapter Three in this report)
- SH-130 Lessons Learned System (Chapter Four in this report).

Finally, this report presents some conclusions from the research.

1.2 Product Deliverable No.1—CDA Procurement Process Model

For generations, public agencies in the United States used the traditional design-bid-build (DBB) method for delivering highway projects. Now, many public agencies are adopting the Design-Build (DB) delivery method. In the 2002 Design-Build Contracting Final Rule, the Federal Highway Administration (FHWA) strongly encourages the use of the two-phase selection procedures for DB procurement. This report investigated the use of a two-phase process for selecting the provider of highway design-build services by the Texas Department of Transportation (TxDOT). Using two DB projects in Central Texas as case studies, the authors analyzed project documentation, and conducted interviews with TxDOT representatives involved in the procurement. For the first case, authors selected the $1.3 billion State Highway 130 (SH-130) tolled expressway project in Central Texas. Procurement of the SH-130 DB contract was performed before the FHWA Rule was adopted.

In addition, authors examined procurement activities for the $154 million DB contract for another tolled expressway in Central Texas. Though procured by TxDOT, this contract's 2004-award date made its contractual procedures subject to the FHWA rule. As a result, a process was developed that included activities to be performed between the delivery method decision and the contract execution. This process was proposed along with the general guidelines for preparing procurement documents. The model tracked the differences between the SH-130 and the SH-45 SE processes that were attributable to the 2004 advent of the FHWA Rule, including durations and critical activities.

1.3 Product Deliverable No.2—Essential Elements of CDA Master Contract

This report provided an analysis of the essential elements of the Comprehensive Development Agreement (CDA) and the associated lessons learned. The purpose of this research product was to facilitate the preparation of future CDA contracts. This document primarily included findings from the SH-130 project, but it also incorporates some findings from the SH-45 SE project, both currently underway within the Austin District.

1.4 Product Deliverable No.3—Organizational Structures and Communications on the SH-130 Project

This report documented the SH-130 organizational structure and made recommendations for improved CDA-DB project organization. During the investigation, the authors analyzed project documentation and conducted numerous interviews with project representatives, including TxDOT, HDR Engineering, Inc., and LSI representatives. The report is comprised of seven chapters and six appendices.

1.5 Product Deliverable No.5—Plan for Performance Benchmarking of SH-130

This research report contains the plan for the SH-130 performance benchmarking program. It lays out the benchmarking methodology and identifies input and output parameters to be included in the benchmarking of the SH-130 project.

1.6 Product Deliverable No.8—CDA Innovations Workshop CD

This video CD includes multimedia content on the first SH-130 Innovations Workshop held in Austin, Texas on February 16, 2006. A Microsoft document provides a map to the video CD content. The content was structured according to the workshop agenda.

2. Procurement Change Implementation Framework

2.1 Introduction

This chapter proposes a comprehensive approach for the implementation of innovative project delivery methods. During the initial phases of this research project, the research team had the advantage of privileged access to the SH-130 project's environment, and was able to make several observations on the implementation of the design-build approach. Findings suggest that TxDOT employees assigned to the project developed DB practices and routines by adapting existing DBB practices. Consequently, the institutionalization of innovative approaches to project delivery happens concurrently with a deinstitutionalization of the previous approaches. This concurrency produces different effects on the project environment, depending on the mediating action of emerging organizational practices and the various perspectives of the involved parties. Building upon the SH-130 study, the research team developed a conceptual implementation framework for helping owner organizations change their approach to project procurement. In the following sections, we elaborate a problem statement and describe the conceptual framework.

2.2 Needs and Motivations for an Implementation Framework

For organizations such as departments of transportation, other public agencies or private companies, the adoption of a new approach to procure services for delivery of construction projects requires significant institutional changes. Such a fundamental shift involves modifications to both their work processes and organizational structures. Because these adjustments affect many of the organization's basic interests (e.g., provider selection procedures, standard contractual documentation, project organization and staffing, data/information interchange, and communications procedures), they are critical to the success of the change initiative.

2.2.1 Trends and Tendencies in U.S. Infrastructure Project Procurement

In the United States, the infrastructure sector has experienced a number of changes in its approach to project procurement over the last century. Until the end of the 19th century, concurrent delivery of design, construction, and long-term operations was standard, facilitated largely by state statutes and the absence of strong professional organizations (Pietroforte and Miller 2002). These factors, among others, led to a wide application of integrated procurement systems.

In fact, the segmentation of design and construction services was first allowed by the U.S. Congress in 1893; however, the infrastructure sector's use of this split delivery method was not fully assumed until passage of the Federal Aid Road Act in 1916 (Pietroforte and Miller 2002; Rein et al. 2004). Ten years later, with the passage of the Public Buildings Act, the federal government required design and construction services to be procured independently. Subsequently, the Great Depression "eclipsed [both] the private funding of public projects and the use of the combined project delivery methods" (Pietroforte and Miller 2002). Thus, the use of segmented approaches to project delivery increased through World War II and was later reaffirmed in both the 1956 Federal Aid Highway Act (Rein et al. 2004) and the 1972 Brooks Act (Pietroforte and Miller 2002).

The infrastructure sector is currently reencountering the issues surrounding procurement approach change. In response to an increasing demand both for new capacity and for minimizing the impact of construction on motorists, several state agencies are considering alternative delivery methods for new infrastructure projects. After years of using the low-bid approach Design-Bid-Build (DBB) project delivery, these agencies are increasingly turning to non-traditional project delivery. This shift has been made possible by the recent repeal or relaxation of laws and regulations favoring DBB, and by related changes in industry practice (Kennedy et al. 2006; Papernik and Davis 2006).

Among the many emerging non-traditional delivery method options, the Design-Build (DB) approach has become one of the most popular alternatives. In 1990, the Federal Highway Administration (FHWA) initiated a special experimental program (SEP-14—Innovative Contracting) to enable state transportation agencies (STAs) to test and evaluate this delivery method and a few others. The purpose of this program was to identify delivery method alternatives to the traditional DBB method that "provided the potential to expedite highway projects in a more cost-effective manner, without jeopardizing product quality or contractor profitability" (FHWA 2006). Recently, FHWA published a report summarizing findings and lessons learned from the SEP-14 program. This report not only acknowledged the effectiveness of the DB method in shortening project time delivery, but it also observed that agencies could pursue alternative financing paths as a direct result of this schedule benefit (FHWA 2006).

2.2.2 Potential Problems Associated with Changing Project Procurement Approach

Because the decades-long use of the segmented DBB method has so fundamentally shaped employee perceptions and organizational structures and practices, implementing a combined procurement approach constitutes a paradigm shift for the state agencies adopting it. Studies have found that "as agencies attempt design-build for the first time, they are constrained by the low-bid culture in their organizations" (Molenaar and Gransberg 2001). In a report to Congress on Public Private Partnerships (PPP), the U.S. Department of Transportation acknowledged these difficulties, reporting that, "states not accustomed to this method of procurement can find it difficult to oversee these types of projects (USDOT 2004)." In addition, although combined procurement of services is expected to reduce transactional costs for delivering a project (Pietroforte and Miller 2002), the different nature of this type of procurement usually results in state personnel spending extensive amounts of time experimenting and developing new organizational routines to support the procurement change (USDOT 2004). These time excesses are often justified by a wider concern that traditional safeguards embedded in traditional procurement and financing approaches can be lost in the change process (USDOT 2004). These challenges to changing a project's procurement approach are summarized below in the problem statement of this research effort.

2.2.3 Problem Statement:

Since the combined project procurement approach is a response to changes in the industry environment, owner organizations are compelled to seek ways to adapt their organization to the new approach. This adaptation requires the development of new work processes along the procurement cycle, and involves the implementation of these processes within new organizational structures.

2.3 Background

This background section includes two sub-sections. In the first, the concept of a *procurement cycle* is introduced, and a framework is developed for mapping project phases and activities under different project delivery approaches. Also, concepts underlying the framework are defined (e.g., *procurement*, *project delivery method* and *project contractual framework)*. In the second sub-section, the authors summarize significant contributions from the literature pertaining to infrastructure procurement.

2.3.1 Procurement Cycle

A construction project life cycle is commonly represented in the literature as a succession of function-based phases along a timeline. Such common illustrations of the life cycle are based on an owner-centered view of the cycle. Because this view is based on the traditional DBB project delivery method, it assumes owners usually self-perform most of the functions (except the construction). As such, this representation does not reflect project components that might be outsourced, and therefore obscures any relationships between entities delivering different project components.

An alternative representation of the life cycle is proposed in Figure 2.1. According to this view, during the initial project phases, the Owner (or its agent) decides whether to outsource the delivery of some project functions (e.g., planning, design, construction, etc.), and how to deliver the outsourced functions (e.g., segmented vs. combined). In U.S. construction industry language, these decisions generate what is commonly called the *project delivery method* (or system). According to one accepted definition, "…a project delivery method […] defines the relationships, roles, and responsibilities of project team members and the sequence of activities required to complete a project" (Walewski et al. 2001). The selection of the project delivery method establishes the approach to delivering different components of the projects.

When a project component (e.g., design in Figure 2.1) or a set of components (e.g., design and construction in Figure 2.2) is outsourced, the corresponding project life cycle phase includes two separate sub-phases, a contract procurement phase and a contract execution phase. These phases can be represented by a cycle, the *procurement cycle* of that given project component (or set of components). Using a common definition of procurement, a descriptive model for a generic procurement cycle is proposed in Figure 2.3. According to this model, an Owner organization is first required to decide on a project delivery method. This decision allows the owner organization to identify the number of procurement cycles (and service providers) required for the complete delivery of a project.

Each cycle include two phases. During the first phase, a procurement process allows the Owner organization to identify a provider and draw up a contractual agreement. During the second phase, an execution process regulated by the contractual agreement, allows the Provider to produce the contracted project component. Depending on the contractual agreement, the Owner organization retains a certain level of involvement in overseeing the execution process and collects information for acceptance of the final product.

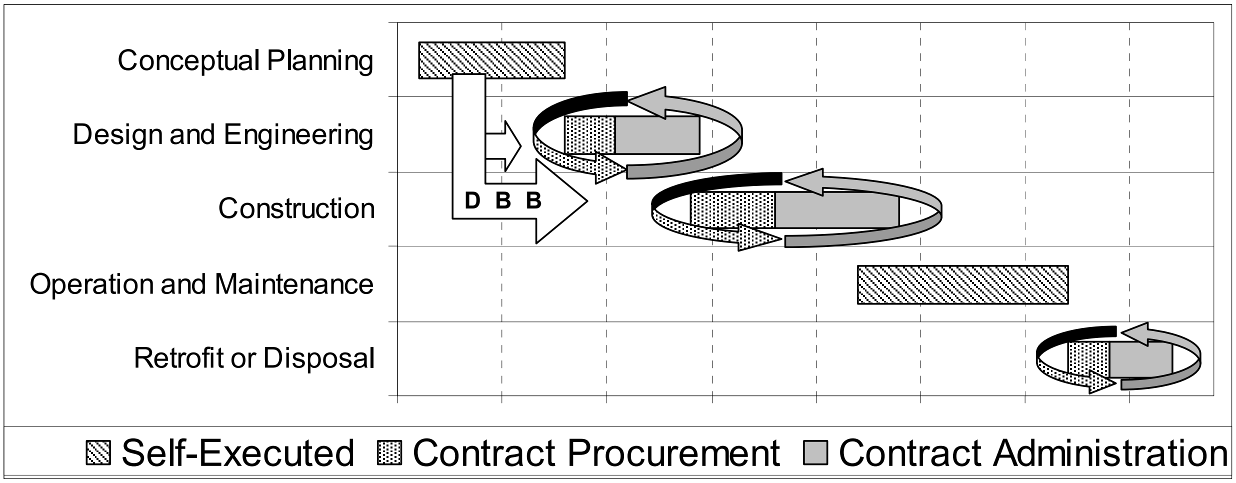

Figure 2.1: Segmented Procurement Cycles in Project Life Cycle

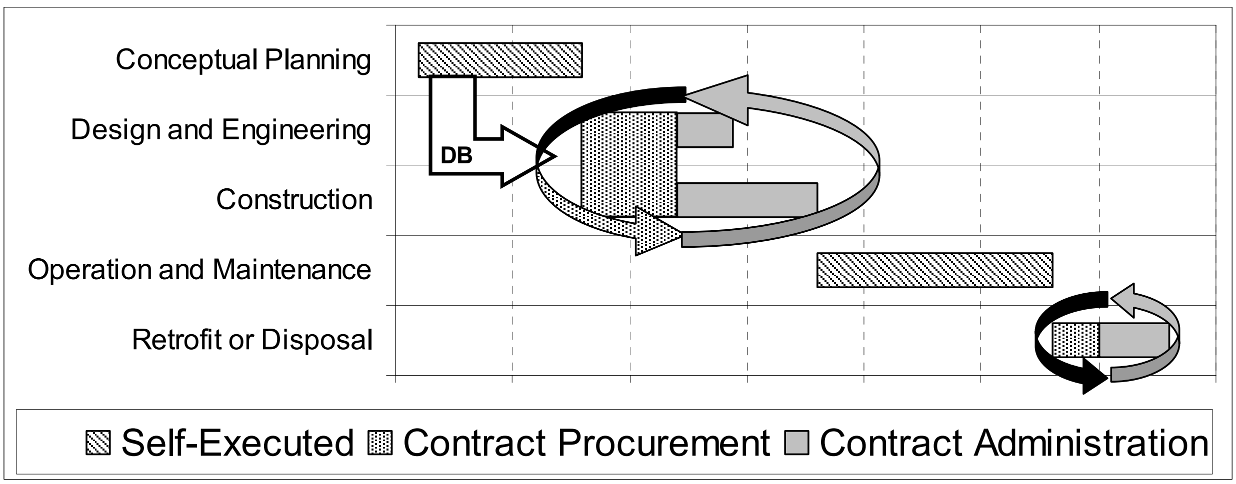

Figure 2.2: Combined Procurement Cycles in Project Life Cycle

2.3.2 Literature Review

The framework represented in Figure 2.3 for a generic procurement cycle was used to map significant contributions from the literature pertaining to infrastructure procurement. The literature review explored several sources, including:

- ASCE journals and conference proceedings;
- Other relevant referred journals in the construction and project management area;
- Civil engineering magazines;
- State transportation agencies websites; and
- Federal Highway Administration website.

Table 2.1 includes references to literature sources.

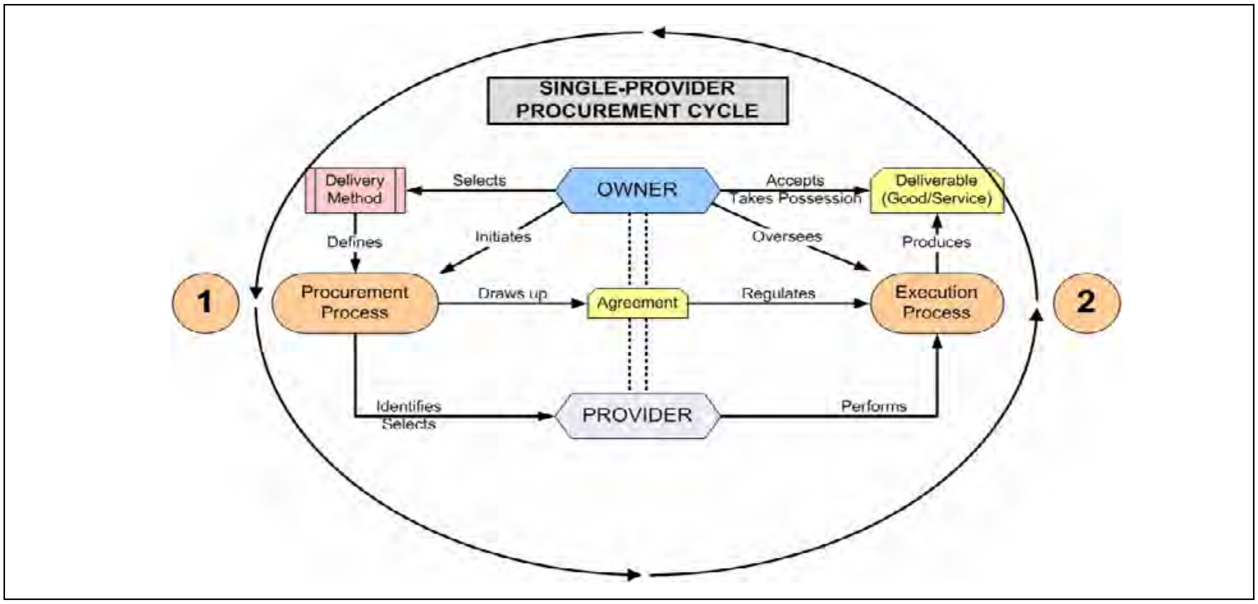

Figure 2.3: Procurement Cycle

Contributions in the available literature are concentrated on studies of building projects with a few contributions involving transportation projects. In addition, most of the information related to changing procurement method concerns contract procurement processes. The most investigated processes are the selection of delivery methods and the selection of service providers. Few papers are interested in how the choice of delivery method affects the procurement process. While upfront processes are heavily investigated, studies on contract administration processes for combined delivery methods are scarce and mostly anecdotal.

Additional significant contributions found include: (a) few longitudinal studies on the historical evolution of government procurement strategies in both the U.S. (Miller 1997; Pietroforte and Miller 2002; Rein et al. 2004) and the UK (Dowd 1996); and (b) suggestions for changing procurement approach at the organizational level for Owners (Walewski et al. 2001; Yates 1995), Design Consultants (Smith 2005), and Contractors (Yates 1995).

Table 2.1: Summary of Project Delivery Literature

#	*Phase*	*Topic*	*Reference*
1	Contract Procurement	Selection of Project Delivery Method	(Akintoye 1994; Anderson and Oyetunji 2001; Hale 2005; Ibbs et al. 2003; Konchar and Sanvido 1998; Miller and Evje 1999; Molenaar and Songer 1998; Songer and Molenaar 1996)
2	Contract Procurement	Design-Build Procurement Process	(Molenaar and Gransberg 2001)
3	Contract Procurement	Contractual Documentation	(Anderson et al. 2004; Anderson and Russell 2001; Bing et al. 2004; Bing et al. 2005; Grimsey and Lewis 2002; Knight et al. 2002; Schaufelberger 2005; Smith 2001; Songer and Ibbs 1995; Tookey et al. 2001; von Branconi and Loch 2004)
4	Contract Procurement	Provider Selection	(Gransberg and Molenaar 2003; Molenaar and Gransberg 2001; Molenaar et al. 2004; Palaneeswaran and Kumaraswamy 2000; Shane et al. 2006)
5	Contract Execution	Contract Administration	(Anumba et al. 1997; Anumba et al. 2002; Anumba and Evbuomwan 1997; Elvin 2003; Smith 2005)

2.4 Conceptual Implementation Framework

This section describes the proposed Changing Project Procurement Strategy (CPPS) implementation framework. The CPPS Implementation Framework has been developed to assist STAs in implementing changes in their project procurement strategies; it not only provides agencies with a conceptual map of decisions significant to the new scenario, but it also helps them manage and regulate the implementation process at the project level. The organizational-level component of the framework provides input for agency-wide change by identifying new decision paths that are generated by the new approach. The project-level component of the framework, on the other hand, affects organization-wide change by being used repetitively on every project delivered with the new approach until the agency becomes familiar with it.

As illustrated in Figure 2.4, the proposed framework is composed of the implementation process (IP) itself plus two supporting processes, the knowledge-building process (K) and the implementation assessment process (IA). The activities of these processes are divided into several phases. The first two phases comprise the implementation process at the organizational level; during these phases STA officers need first to define the organizational project procurement strategy, and then to identify projects to be developed through a specific project procurement approach. The next two phases comprise the implementation process at the project level, and depend on the specific project delivery method for their specifications. As the implementation of delivery methods varies, the project-level implementation process can be customized according to the specific delivery cycle. The CPPS processes and phases are described in more detail in Figure 2.4 and subsequent verbiage.

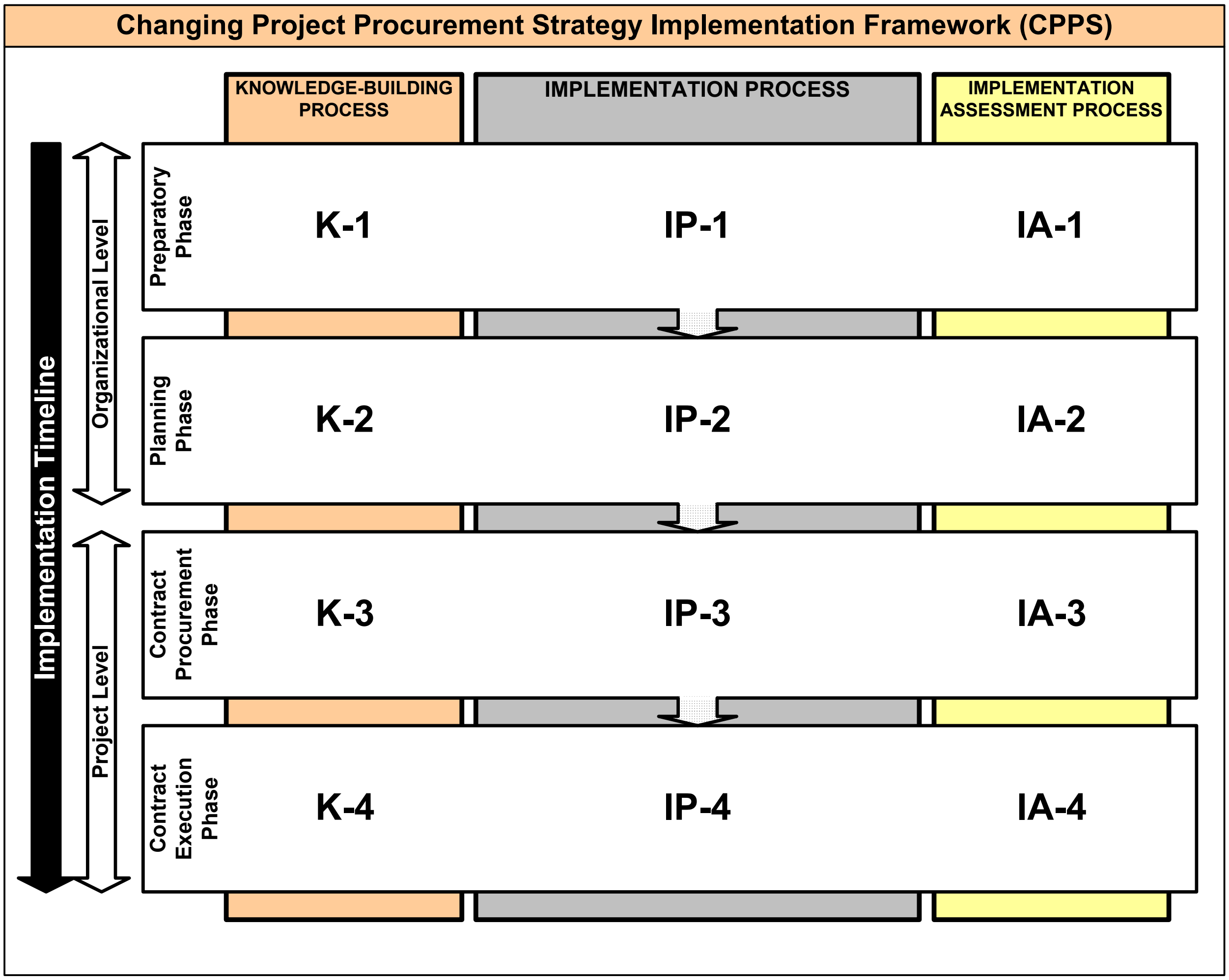

Figure 2.4: CPPS Implementation Framework

CPPS FRAMEWORK CONCURRENT PROCESSES

The **CPPS Implementation Process (IP)** is the plan to implement the new procurement strategy beginning from the preparatory phase all the way through the contract execution phase. This process facilitates implementation of the new procurement strategy by: (a) identifying decisions significant to the problem of changing procurement strategy, and (b) aligning project practices with organizational goals.

The **CPPS Knowledge Building Process (K)** is the plan to manage knowledge under the new procurement strategy, from the preparatory phase all the way through the contract execution phase. This process induces organizational learning by: (a) collecting, verifying, storing, and disseminating lessons learned from the implementation effort, and (b) identifying sources of information on newly introduced project procurement approaches.

The **CPPS Implementation Assessment Process (IA)** is the plan to assess the accomplishment of the new procurement strategy, from the preparatory phase all the way through the contract execution phase. This process promotes continuous improvement by: (a) providing internal and external benchmarking, and (b) providing feedback on implementation progress to organizational decision makers.

ORGANIZATIONAL-LEVEL IMPLEMENTATION PHASES

Preparatory Phase: This phase focuses on identifying information available at the organizational level that can be utilized at the planning and project levels to implement new procurement approaches. The preparatory phase is driven by high-level organizational personnel and has three objectives: (1) to determine if new delivery approaches are available for use, (2) to define the organizational project procurement strategy, and (3) to initiate the information loop between organization-level and project-level activities.

Project Planning Phase: This phase is performed by organizational-level personnel (i.e., district and/or division personnel) and focuses on identifying transportation needs and constraints, selecting prioritized projects, and making early decisions on the project procurement approach. The project planning phase leads to (1) an initial project procurement approach compatible with both the organizational and project objectives, and (2) a project management team for initiating and carrying out the procurement.

Design-Build Contract Procurement Phase: This phase is performed by project-level and/or organizational-level personnel and focuses on selecting project service providers, allocating project risks, and establishing the project's necessary contractual relationships. The contract procurement phase leads to an established contractual framework between agency and the selected project service provider.

Design-Build Contract Execution Phase: This phase is performed by project-level personnel (i.e., project management team) and focuses on monitoring provider performance, managing the contract, making payments for work performed, and accepting the final deliverables. To reach these phase objectives, the project management team needs to set up all the project organization and communications structures necessary for monitoring and assisting the provider during the project delivery. The contract execution phase leads to an established project execution framework between agency, the selected project service provider, and other interested parties.

2.5 Related Research Activities

For the duration of project 0-4661, the research team periodically monitored and assessed the implementation of the design-build delivery method on the SH-130 project. Figure 2.5 identifies the role of the research deliverables within the implementation framework. Completed deliverables such as P1, P2, and P3 aimed to identify implementation processes and to develop a base for building knowledge on DB implementation. These reports also facilitated the identification of benchmarking metrics for assessing the implementation effort. Three other deliverables are focused on specific processes of the framework. A workshop was held in February 2006 to communicate SH-130 project innovations to the TxDOT community. Approximately 200 TxDOT employees around the state attended this event in video conferences. The attendees' assessment of the workshop was encouraging; they rated it as "very helpful" giving it a score of "4" on a 1-5 scale. When required to list sessions that they found more helpful, 42 percent of the attendees identified the two sessions on (a) Procurement and contracting challenges, and (b) SH-130 Organizational structures and communication. In addition, 40 percent of the attendees valued the interactive Questions and Answers session on Organizational structures and communication. Finally, when attendees were asked if a similar workshop should be held in the future, the response was overwhelming with 94 percent of the group answering positively.

The researchers edited footage to the presentations at the event and produced a video CD (P8) for TxDOT employees interested in implementing DB on future projects. A lessons learned system (P6) was also developed to accompany this report. Chapter 4 describes the system while the system's user manual is provided in Appendix B. The system is populated by about 100 lessons collected during investigations of previous deliverables (P1, P2, P3, and P8).

Finally, the research team identified a set of metrics for benchmarking the DB implementation and developed a plan for this benchmarking (P5). Chapter 3 describes the status to date for the benchmarking effort. In addition, preliminary analysis of benchmarking data is offered in Appendix A.

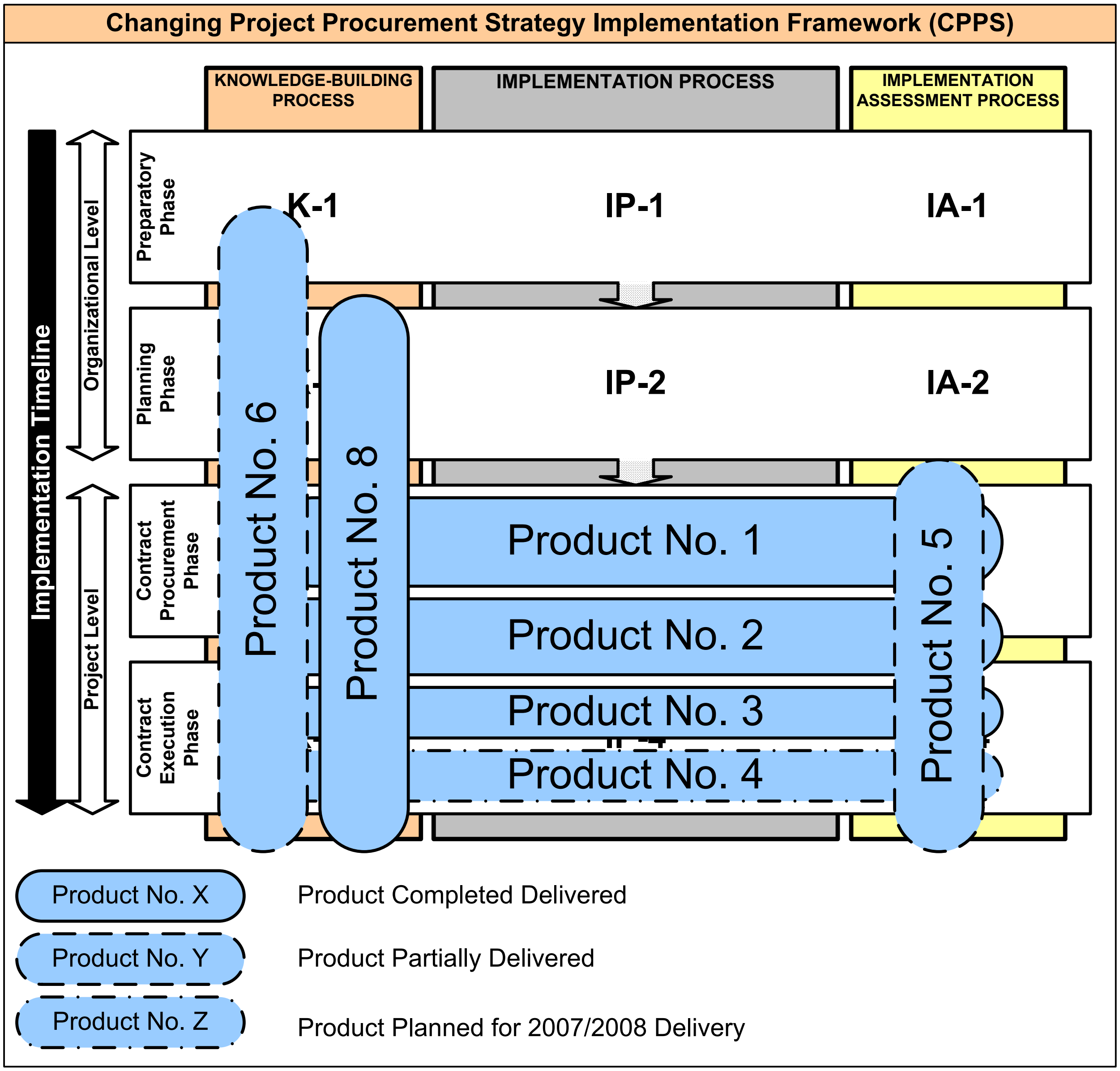

Figure 2.5: Research Deliverables

3. Benchmarking Study: Overview of Findings

3.1 Status of Benchmarking Task

The framework of benchmarking SH-130 consists of seven DB and five DBB projects. Out of the seven DB projects, five are out-of-state and two are in-state. However all of the DBB projects are in Texas. To date, four sets of out-of-state DB project data have been collected. Partial data of one out-of-state and one in-state DB project has been collected. Construction on SH-45 SE has not yet begun due to environmental litigation. Therefore, the data of this project could not be collected. Because all of the in-state DBB projects are under construction, their preliminary data has already been collected and their final project completion data will be collected in the near future. Despite the efforts of the research team, the data from the I-10 reconstruction project in San Antonio could not be collected. Similarly, pre-project completion data from the SH-130 project could not be collected. Therefore, the analysis of these projects as it now stands does not include SH-130.

3.2 Inputs Analysis

One of the main objectives of this benchmarking study is to determine the significant input factors that affect project performance. To accomplish this objective, the research team collected about 40 input factors (project characteristics) from all the projects. In this analysis, about 30 input factors have been analyzed and shown. Because the data received from the candidate projects was incomplete, the remaining input factors resisted analysis.

The analysis of the input factors is shown comparatively between DB and DBB projects in Appendix A1. Some of the input factors are analyzed at the project level and some are at the contract levels. For the DB projects, all the inputs are at the project level, whereas, because some DBB projects have multiple contracts, some of their inputs are analyzed at the contract level.

Figure A1.1 shows the average costs of contracts under both the DB and DBB approaches. The project cost includes the cost of design and construction only. The total cost of all the projects for benchmarking is estimated as U.S. $5 billion excluding the cost of SH-130. The average cost per DB contract is U.S. $387 million, while the average for DBB contracts is U.S. $154 million. If the average cost per project is calculated, then for DBB projects, the average cost will jump to $600 million per project. Figure A1.2 shows the percentage of total project cost by type of projects. The percentage of total reconstruction cost is about 68 percent for DB and 70 percent for DBB projects. Therefore, the projects in both cases are equally distributed. Figures A1.3 to A1.30 show the different types of inputs (project characteristics) for DB and DBB that are identified during the data collection phases.

3.3 Outputs Analysis

The timelines for four of the six DB projects studied are shown in Appendix A2. Each timeline charts the detail design and construction phases of the project. It shows when the project began the detail design and when the major activities like design, ROW acquisition, utilities, and construction were started and completed. The timeline of DBB projects are not shown because most of these projects are under construction. Computation of the output metrics is included in Appendix A3.

3.3.1 Expected Cost Growth

Expressed as a percentage, the expected cost growth is the difference between total contract cost and owner estimated cost divided by owner-estimated cost. The owner-estimated cost is the cost the owner expected before the contract is awarded. The contract cost is the cost the contractor bid during the bidding process. Both of these costs include only design and construction costs. The following formula can be used to calculate this output.

$$\textit{Expected Cost Growth} = \frac{\textit{Total Contract Cost} - \textit{Owner Estimated Cost}}{\textit{Owner Estimated Cost}} \times 100$$

Figure A3.1 shows expected cost growth for DB and DBB projects. The box plot of expected mean cost growth is shown in Figure A3.5. The expected mean cost growth for DB and DBB highway projects is -5.8 percent and -14.8 percent respectively.

3.3.2 Expected Cost per Lane Mile

Expressed in terms of dollars per lane mile, expected cost per lane mile is the ratio of total design and construction contract cost and total lane miles of road. The following formula is used to calculate this output.

$$\textit{Expected Cost per Lane Mile} = \frac{\textit{Total Design and Construction Contract Cost}}{\textit{Total Lane Miles}}$$

Figure A3.2 shows expected cost per lane mile for DB and DBB projects. The box plot of mean expected cost per lane mile is shown in Figure A3.6. The mean expected cost per lane mile of road for DB and DBB highway projects is U.S. \$3.27 million and U.S. \$3.67 million, respectively.

3.3.3 Expected Schedule Growth

Expressed as a percentage, expected schedule growth is the difference between total contract duration and owner estimated duration divided by owner-estimated duration. The owner-estimated duration is the owner-expected time to construct the project before the contract is awarded. The contract duration is the contractor bid duration. Both of these durations include only design and construction durations. The following formula can be used to calculate this output.

$$\textit{Expected Schedule Growth} = \frac{\textit{Total Contract Duration} - \textit{Owner Estimated Duration}}{\textit{Owner Estimated Duration}} \times 100$$

Figure A3.3 shows expected schedule growth for DB and DBB projects. The box plot of mean expected schedule growth is given in Figure A3.7. The mean expected schedule growth of DB and DBB highway projects is -1.9 percent and 3.38 percent, respectively.

3.3.4 Expected Delivery Speed per Lane Mile

Expressed as day per lane mile, expected delivery speed per lane mile is the ratio of total design and construction contract duration and total lane mile of road. The following formula can be used to calculate this output.

Expected Delivery Speed per Lane Mile= <u>*Total Design and Construction Contract Duration*</u>

Total Lane Miles

Figure A3.4 shows expected delivery speed per lane mile for DB and DBB projects. The box plot of mean delivery speed per lane mile is shown in Figure A3.8. The mean expected delivery speed per lane mile of DB and DBB highway projects is 9 and 30 days, respectively.

4. SH-130 Lessons Learned System

One of the key products of this research project is a lessons learned database titled "TXDOT SH-130 Lessons Learned System." This database was developed by assembling and organizing the lessons learned that were collected throughout this research project. The purpose of the database is to store and disseminate lessons learned from the SH-130 project so that TxDOT personnel will have a reference source when involved in future Comprehensive Development Agreement (CDA) and design-build projects. The database was also designed to incorporate additional lessons learned from the SH-130 project and future projects into the system.

4.1 System Objectives and Scope

The main objective of the system is to provide TxDOT users with an efficient and effective means for managing the lessons learned from this project. However, in order to provide users with a more useful knowledge management system the scope of the system was expanded. Several objectives were developed to guide the design of this database:

- Allow users to search documented lessons learned based on several sorting criteria. Because there are a large number of lessons within this system, it is important that the system provide the user with a search function. This feature will allow the user to examine the lessons related to the areas that they wish to study, rather than having to scroll through the extensive list of lessons.
- Allow users to enter new lessons learned for the SH-130 project and for future projects. Since it is possible that additional lessons learned will be identified after the completion of the research project, the system permits the user to enter new data. In addition, this feature ensures the usefulness of the system for future projects.
- Allow users to enter additional information such as new projects, new contact information, etc. Entering new data will help to keep the system up to date.
- Provide users with an experts' contact information. Although the lessons learned convey the basic dynamics and issues of the situations they address, users may still have additional questions regarding. Including an expert contact list will allow them to pursue further inquiry.
- Provide users with a user's guide for navigating the system. While the database is user-friendly, including a user guide will provide instructions for properly utilizing the system.

4.2 Lessons Learned Content

Upon completion of this database, a total of 101 lessons learned had been collected. Many of the lessons came from the first three research reports 0-4661-P1, 0-4661-P2, and 0-4661-P3. Furthermore, seven more interviews were transcribed so that additional lessons learned could be identified. Finally, nine other lessons learned were taken from the State Highway 130 workshop. A breakdown of the number of lessons learned collected from each source is presented in Table 4.1.

Table 4.1: Lessons Learned Sources and Number

Source	Number of Lessons Learned
Report 0-4661-P1	18
Report 0-4661-P2	12
Report 0-4661-P3	39
Workshop (2/16/06)	9
Additional Interviews	23
Total	**101**

Each of the 101 lessons was structured in a similar manner so that they could be organized efficiently within the system. The lessons were structured as follows:

- Title: Provides a brief description of the lesson learned.
- Context: Gives a brief background explanation of how the lesson learned relates to the overall project.
- Lesson Learned: Illustrates the lesson that was learned from particular project events and situations.
- Impact: Details the ways in which the events and situations affected the project and offers suggestions on how to improve such circumstances.
- Source: Identifies the source of the lesson (report, interview, or workshop).
- Phase: Describes the particular stage of the project to which the lesson relates (planning, contract procurement, design, right of way, utility adjustment, environmental, construction, or general).
- Category: Describes the area of the project to which the lesson relates (CDA procurement process, CDA master contract, project organization, or project communication)
- Project: Identifies the project from which the lesson was collected.

Table 4.2 provides an example of the structure and content of a typical lesson learned contained within the system.

Table 4.2: Typical Lesson Learned

Title	ROW—Proposal Requirement
Context	During the SH-130 proposal phase, proposers were required to identify at least one ROW acquisition firm.
Lesson Learned	Mega projects need more resources on the ground. Increase the number of required ROW acquisition firms commensurate with the scale of the project. (For the SH-130 project at least two firms)
Impact	This change will expedite the schedule and improve quality by providing additional resources and creating competition. Competition between firms will come in a way that those firms will compete for the next section.
Source	0-4661-P1, pg. 39
Phase	Right of Way
Category	CDA Procurement Process
Project	State Highway 130

All of the lessons learned within the system were organized according to the project phase and category to which each lesson relates. A summary breakdown of the number of lessons learned within each phase and category is presented in Tables 4.3 and 4.4.

Table 4.3: Lessons Learned Breakdown by Phase

Phase	Number of Lessons Learned
Planning	1
Contract Procurement	2
Design	13
Environmental	12
Right of Way	14
Utility Adjustment	13
Construction	14
General	32
Total	**101**

Table 4.4: Lessons Learned Breakdown by Category

Phase	Number of Lessons Learned
CDA Procurement Process	24
CDA Master Contract	20
Project Organization	25
Project Communication	32
Total	**101**

4.3 Lessons Learned System

4.3.1 System Overview

The TxDOT SH-130 Lessons Learned System is a computer program with a standard user interface. The database was developed with the software program MS Access. This software was chosen because all TxDOT computers are equipped with MS Access and many TxDOT users are familiar with MS Access. The system allows users to access documented lessons learned, enter new data and information, view expert contact information, examine the user guide, and print reports.

4.3.2 System Components

The TxDOT SH-130 Lessons Learned System is comprised of six main components:

- Lessons Learned Search Form: The search form allows users to sort through all lessons learned contained within the system. The user may choose to search by phase, category, or project. They may also choose to view all lessons learned.
- Data Entry Forms: There are a total of five data entry forms, which allow the users to enter new information that is not already contained within the system. Such information includes new lessons learned, new projects, and new expert contact information.
- Expert Contact Information: The expert contact list provides the user with contact information for TxDOT personnel who are experts in their particular field (i.e. right of way, utility adjustment, construction, etc.) of work.
- System User Guide: A system guide labeled “User Guide” provides information to users on how to use the system. In addition, there are “Help” forms for each of the main forms to assist the user in utilizing that particular form.
- Reports: The system incorporates three different reports that users may print out as references when they are not logged onto the system.
- Menu Bar: The menu bar is displayed at the top of the screen at all times while the system is in operation. The menu bar allows the user to decide which functions they wish to execute. Such functions include accessing lessons learned, entering new lessons learned, entering new information, viewing the expert contact list, viewing the user guide, and exiting the system.

5. Conclusions

5.1 What the Researchers Did

The research effort was conducted on a multi-objective agenda to investigate various issues related to the adoption of the DB delivery approach for the delivery of a large highway project. First, researchers investigated issues and lessons on contract procurement activities. As a result, a model of the new procurement process was developed (Product No.1) and an analysis of the contractual agreement was conducted (Product No.2). A set of lessons learned by TxDOT during the procurement of the SH-130 project was also identified. Later, researchers investigated issues and lessons on contract administration activities. The outcome of these investigations was a set of recommendations for organizing DOT project team and managing the communication flows between project parties (Product No.3).

To communicate SH-130 innovations and emergent practices to the statewide TxDOT organization, researchers and Austin-based TxDOT staff organized a teleconferenced workshop. This workshop was attended by about 200 TxDOT employees from more than 20 locations. Videos of the event were edited and assembled into a CD to provide a training tool for TxDOT employees (Product No.8).

Finally, researchers identified a set of metrics to benchmark the implementation of the DB method and began collecting data on peer-projects both in- and out-of-state (Product No.5). A Lessons-Learned System was also developed and populated with the more than one hundred lessons collected during the investigations (Product No.6).

5.2 What the Researchers Found

The implementation of a new delivery method such as DB in an organizational environment where DBB is an institutionalized practice involves significant modifications to existing work processes and organization structures and the need to counter substantial resistance to change. Specifically, the project level is one area where such resistance occurs. As opposed to top managers who are aware of global change initiatives, project-level personnel operate on established organizational routines designed for maintaining traditional roles and responsibilities. When a new approach is employed, existing routines can actually inhibit the desired transformation from moving forward. In addition, the decades-long practice of delivering projects through DBB has established cultural barriers. While such resistance can constitute a serious challenge to implementation, the researchers found two challenges that demanded senior management effort in order to ensure a successful project: (1) transferring organizational goals for change into project practice, and (2) establishment of new organizational routines to facilitate organizational-wide programmatic implementation.

5.3 What This Means

The adoption of the DB method needs to be planned and sustained by organization management, and a set of industry practices needs to be identified and adapted to the organizational environment.

- Internal and external project stakeholders need to be educated on these practices to decrease resistance.
- Knowledge on the DB method needs to be collected to close the information loop between project and organization levels and to develop organizational training.
- An assessment of the implementation effort is necessary to identify needed adjustments at the project level and to provide organizational stakeholders with quantitative measures of the effectiveness of different delivery methods under different circumstances. This quantitative information will support future decision makers in making early, informed decisions on preferred project delivery approach.

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Appendix A1. Benchmarking Data: Input Analysis

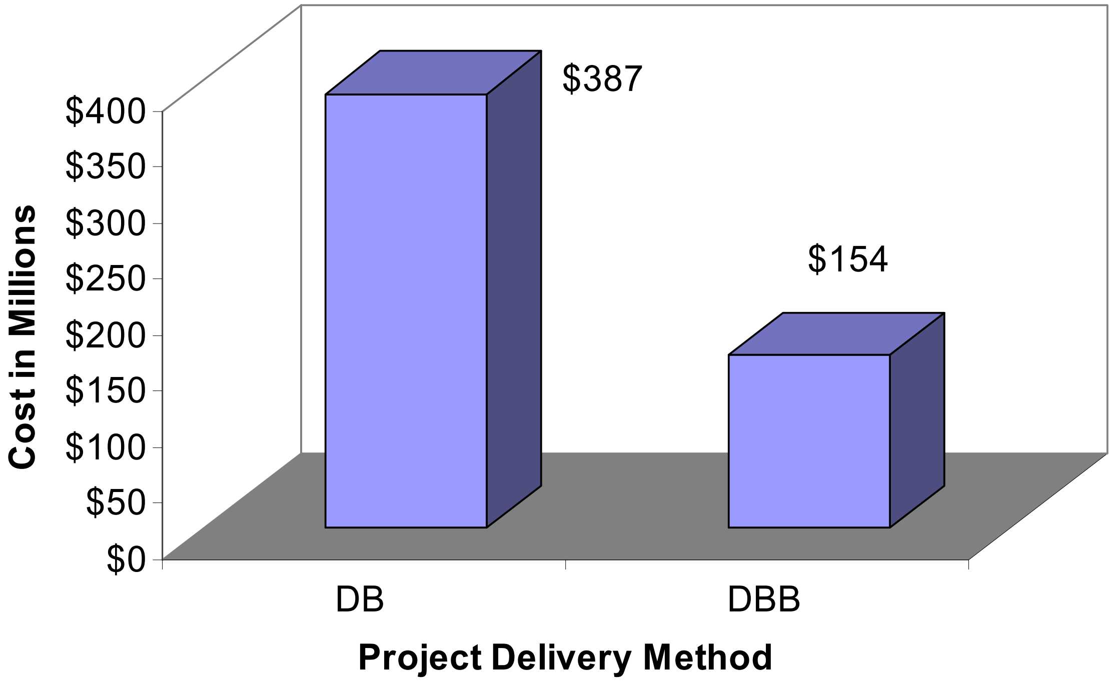


Figure A1.1: Average Project Cost by Project Delivery Method

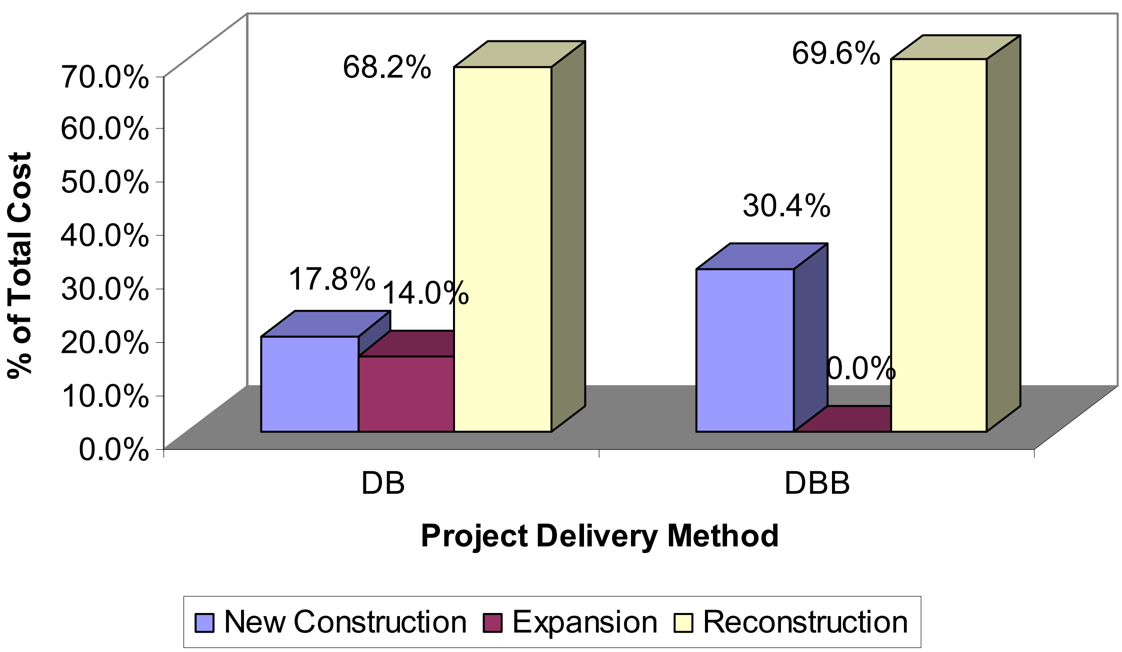


Figure A1.2: Percentage of Total Project Cost by Types of Projects

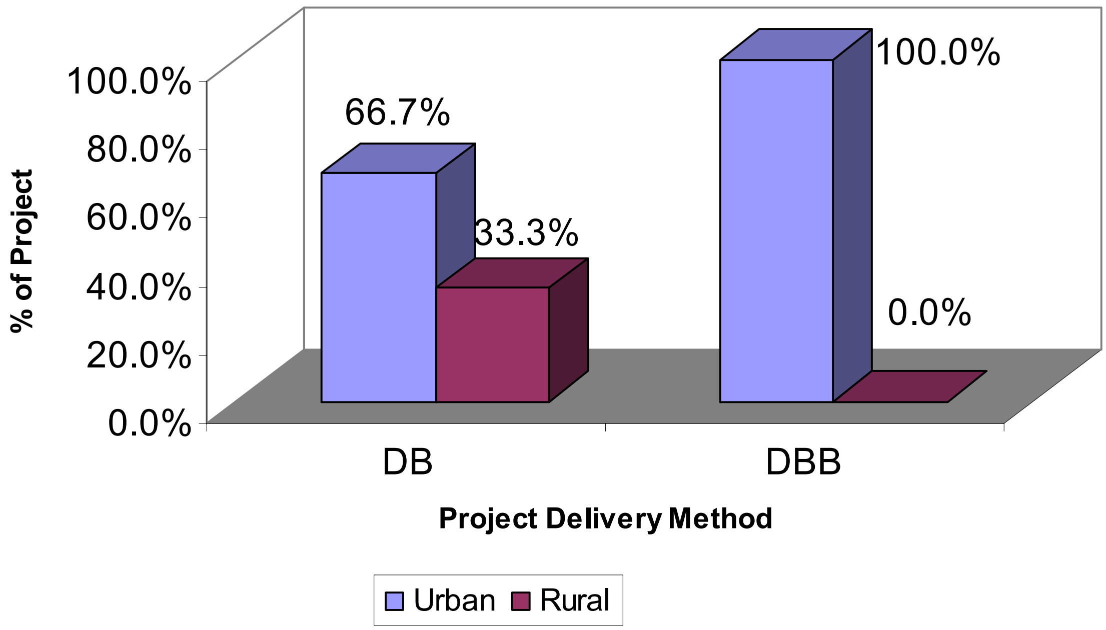


Figure A1.3: Percentage of Total Projects by Location

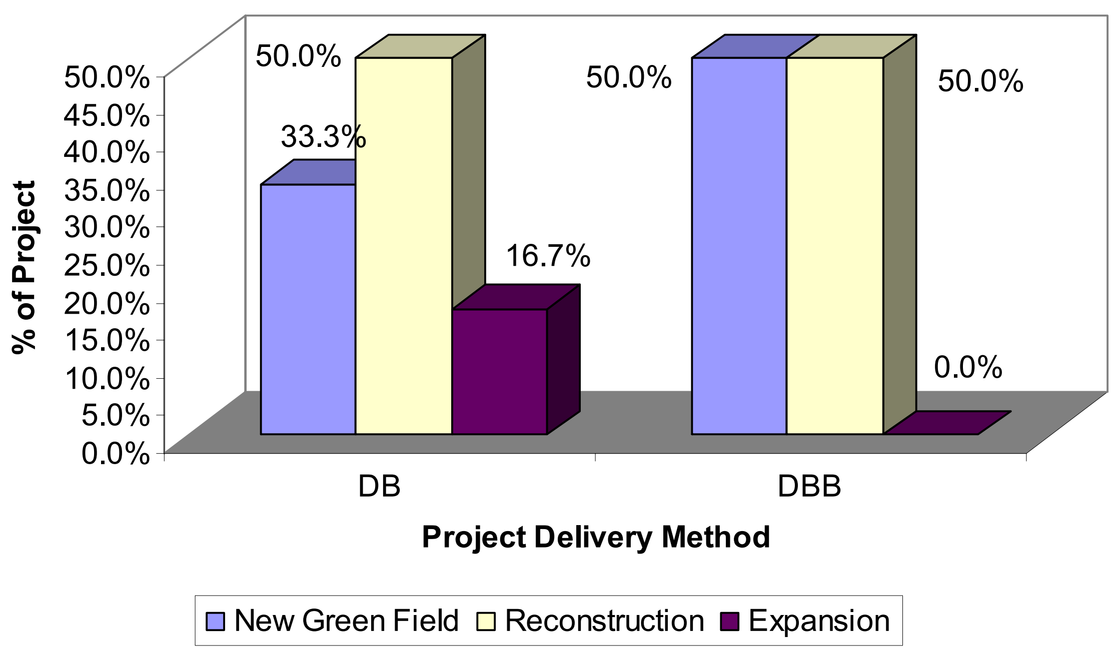


Figure A1.4: Percentage of Total Projects by Nature

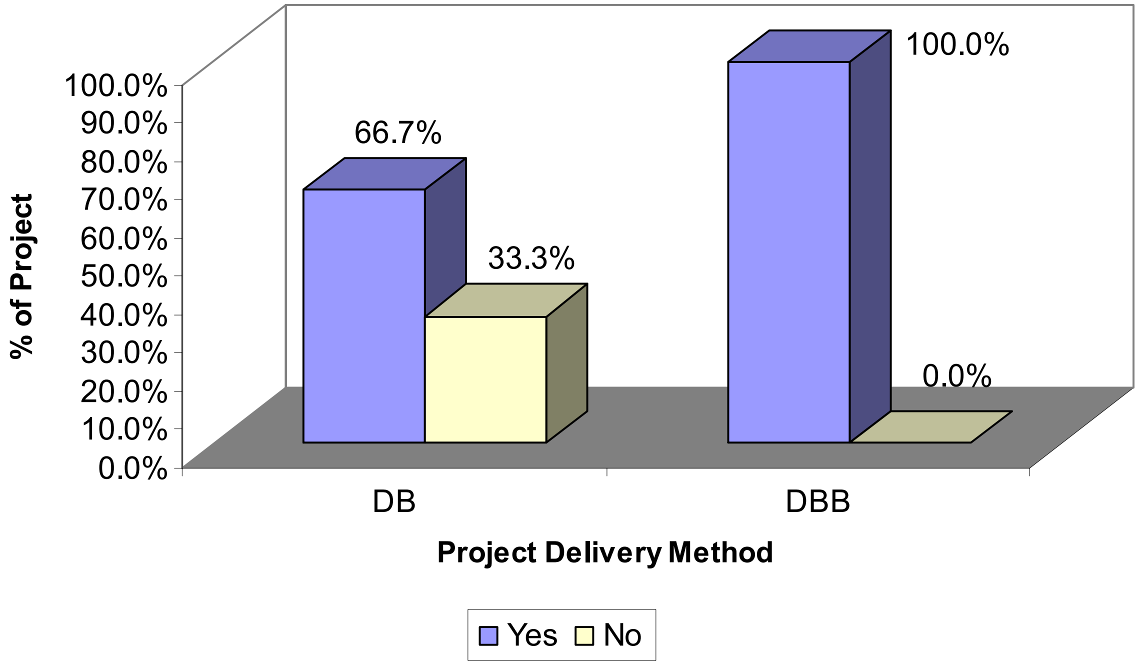


Figure A1.5: Percentage of Projects Constructed with Traffic

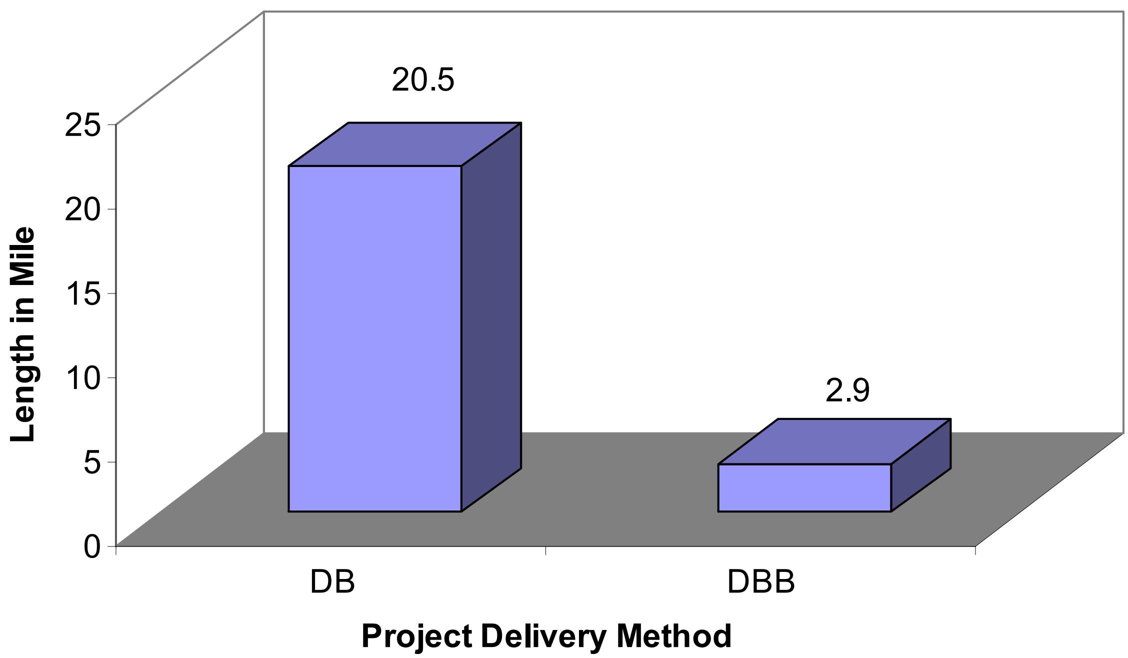


Figure A1.6: Average Length of Road per Contract

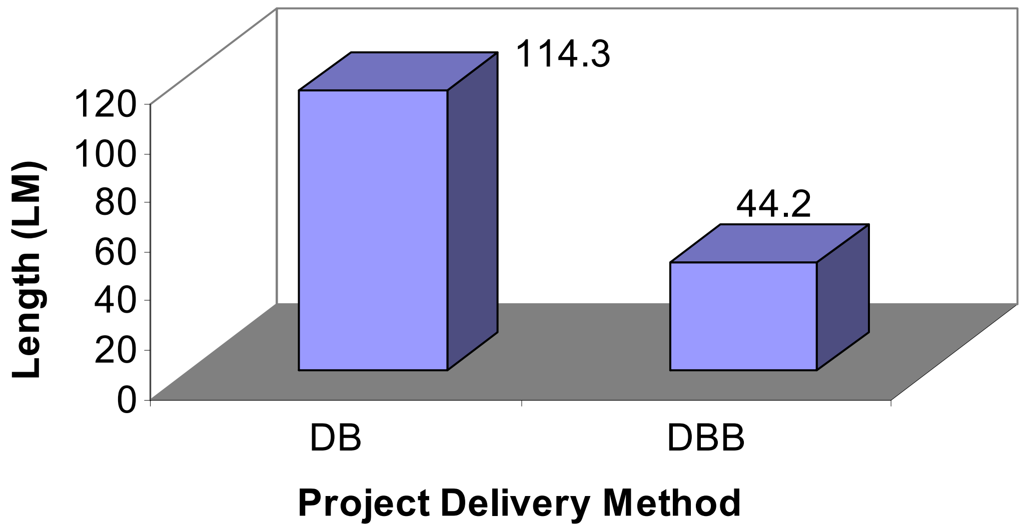


Figure A1.7: Average Lane Mile Length of Road per Contract

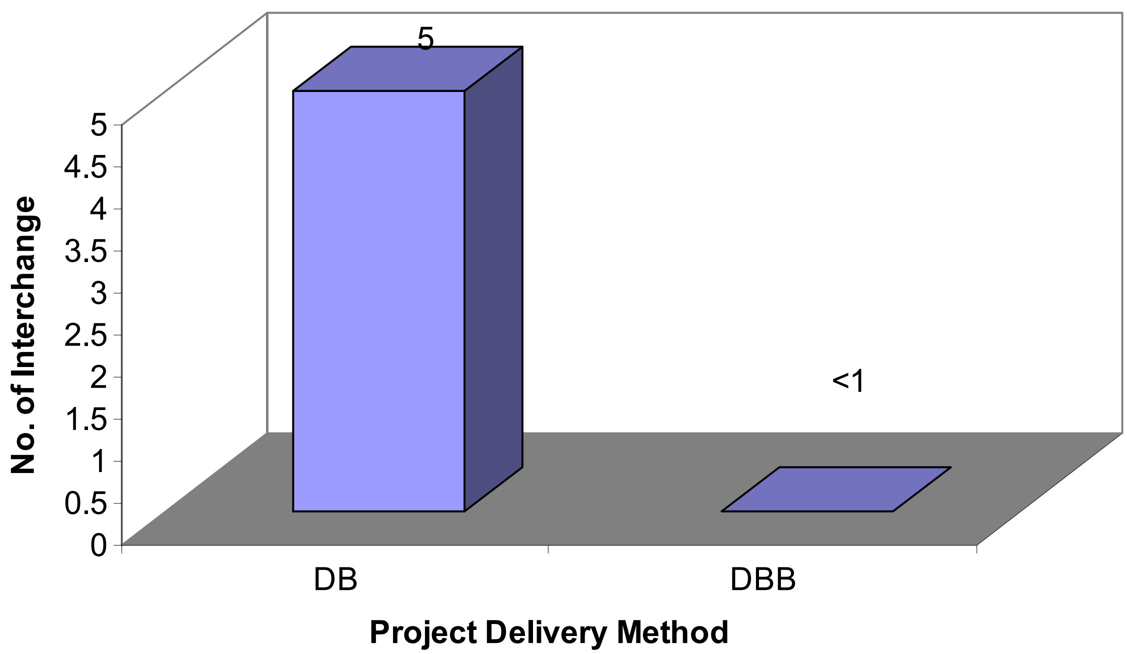


Figure A1.8: Average Number of Interchanges per Contract

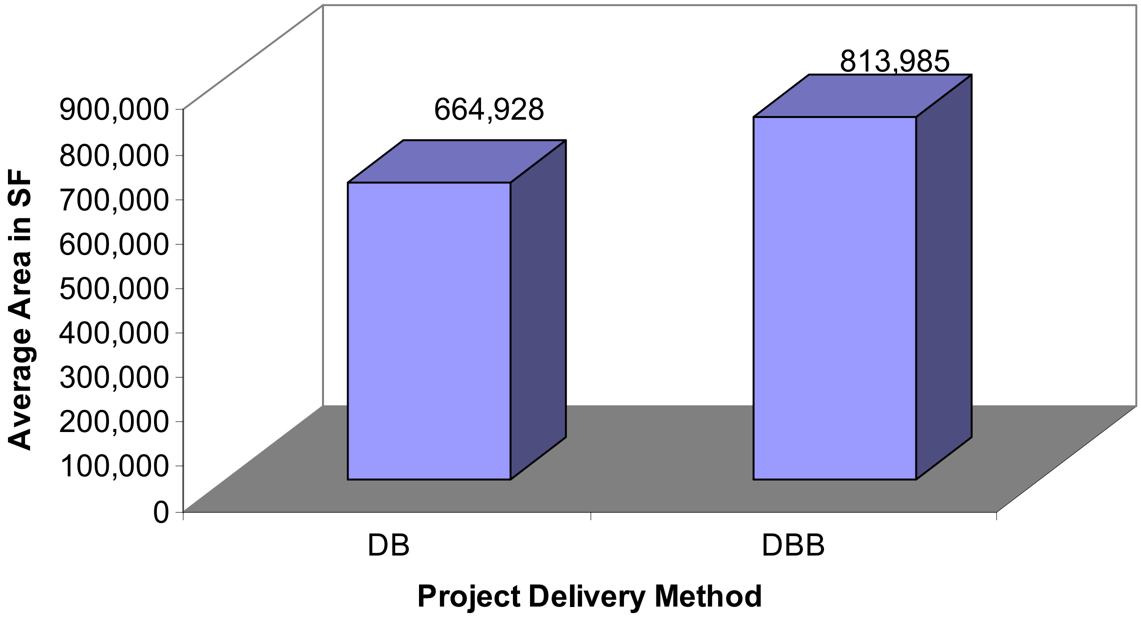


Figure A1.9: Average Area of Bridge in Square Feet per Contract

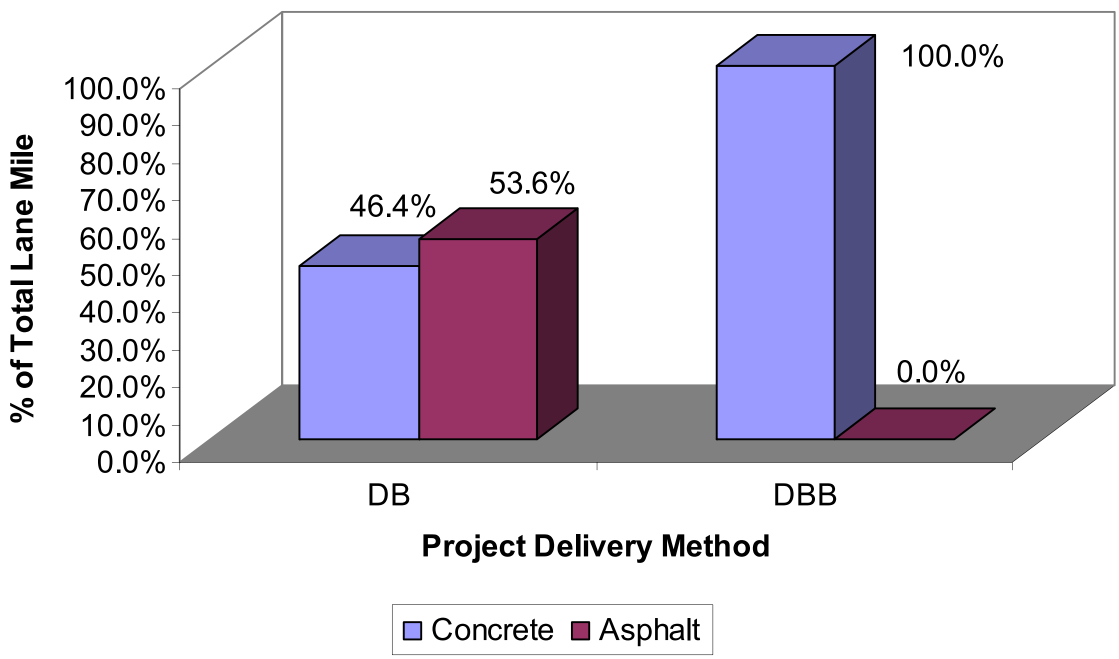


Figure A1.10: Percentage of Total Lane Miles by Pavement Type

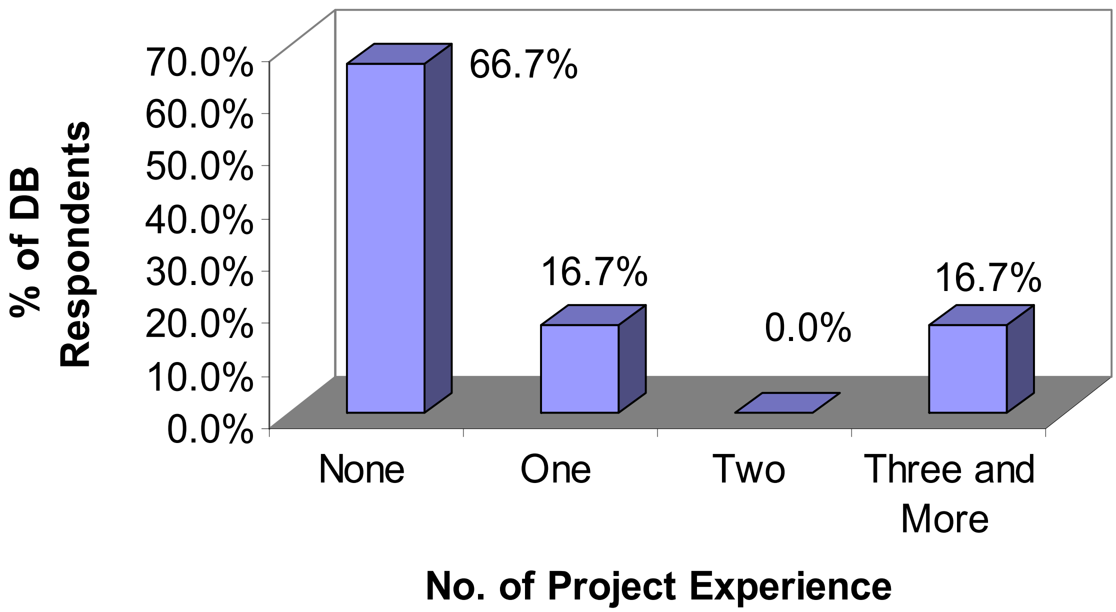


Figure A1.11: Percentage of DB Respondents with Previous DB Experience

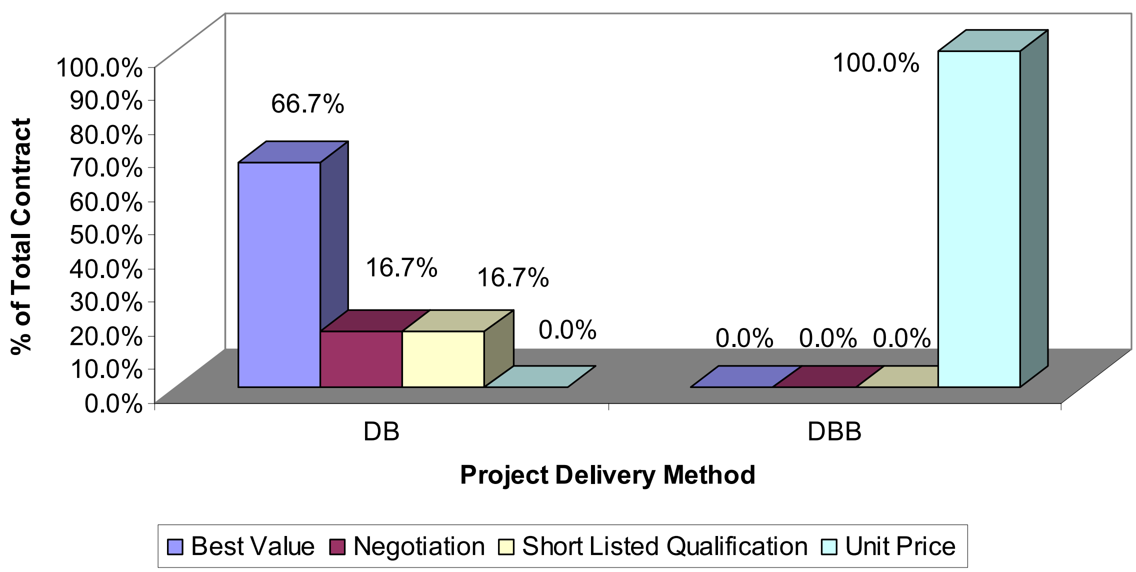


Figure A1.12: Percentage of Contracts by Contract Award Method

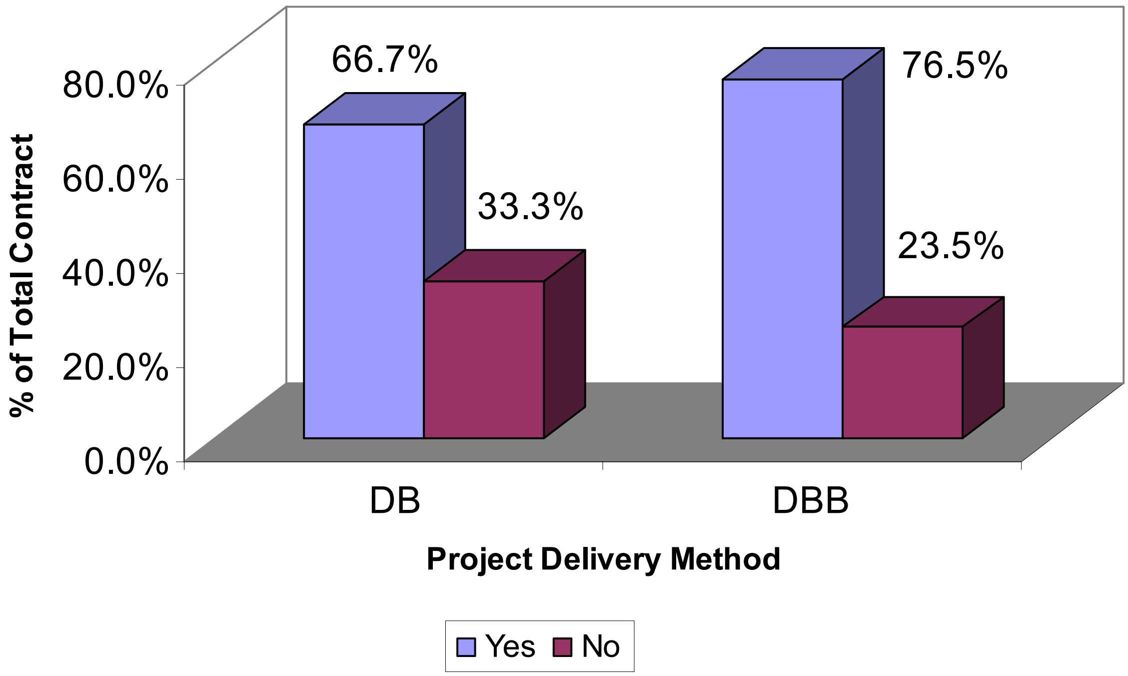


Figure A1.13: Percentage of Total Contracts by Liquidated Damage Provision

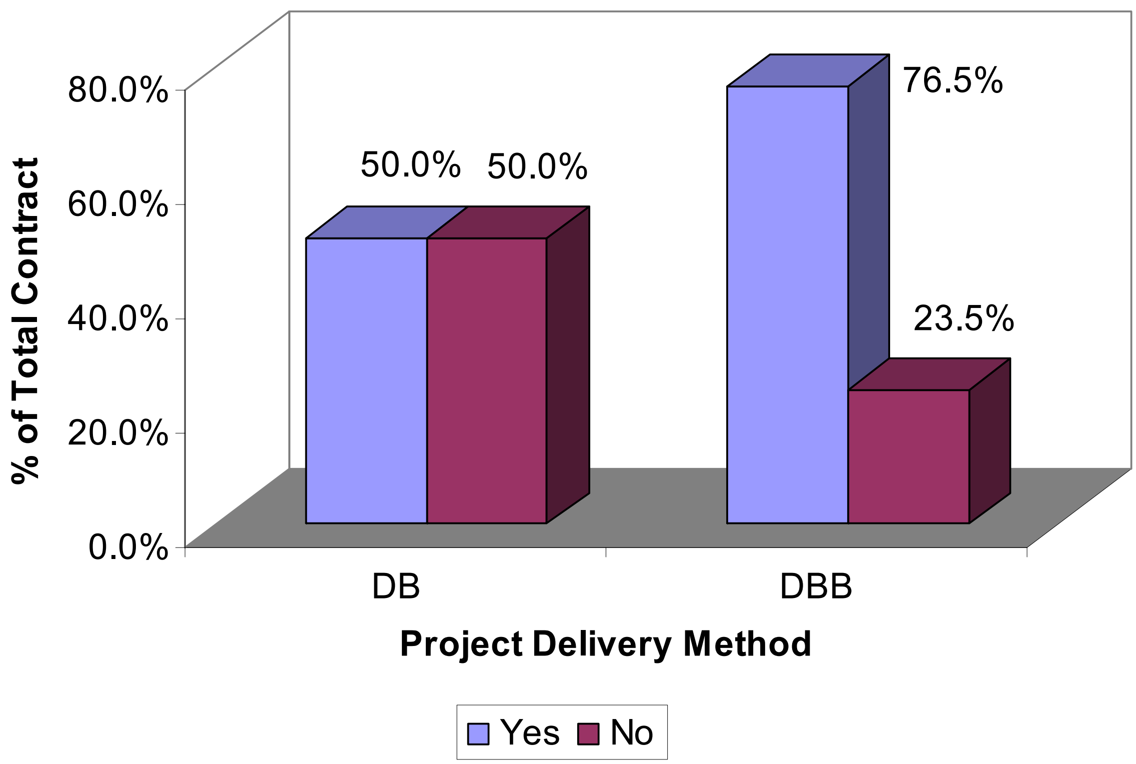


Figure A1.14: Percentage of Total Contracts by Schedule Performance Provision

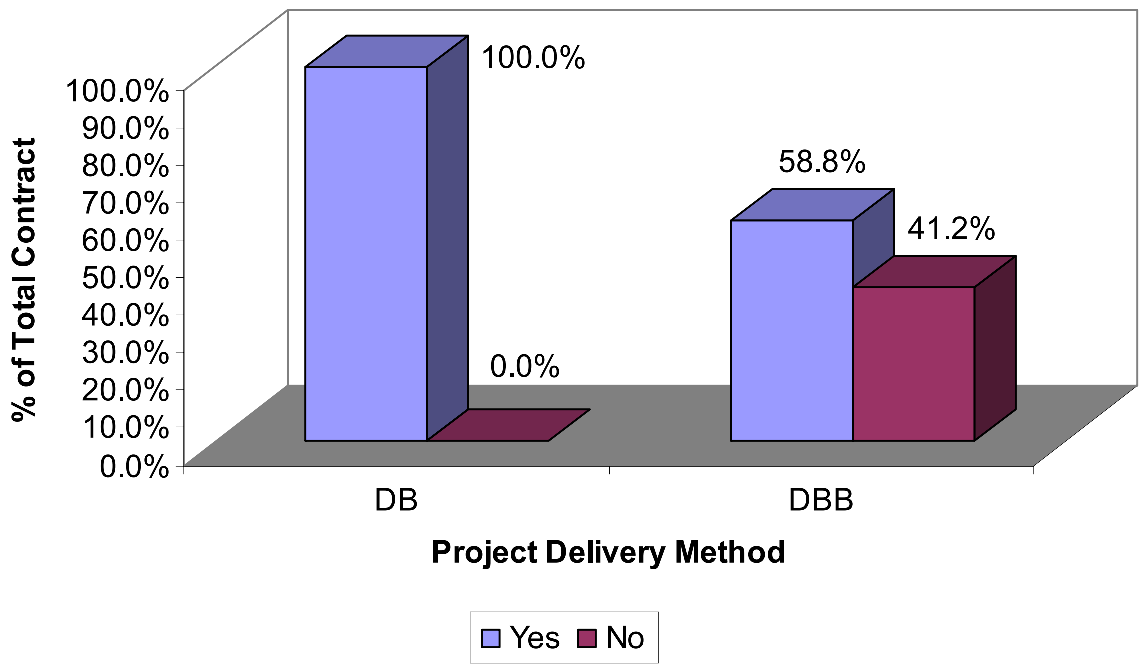


Figure A1.15: Percentage of Contracts with Disincentive for Late Completion Provision

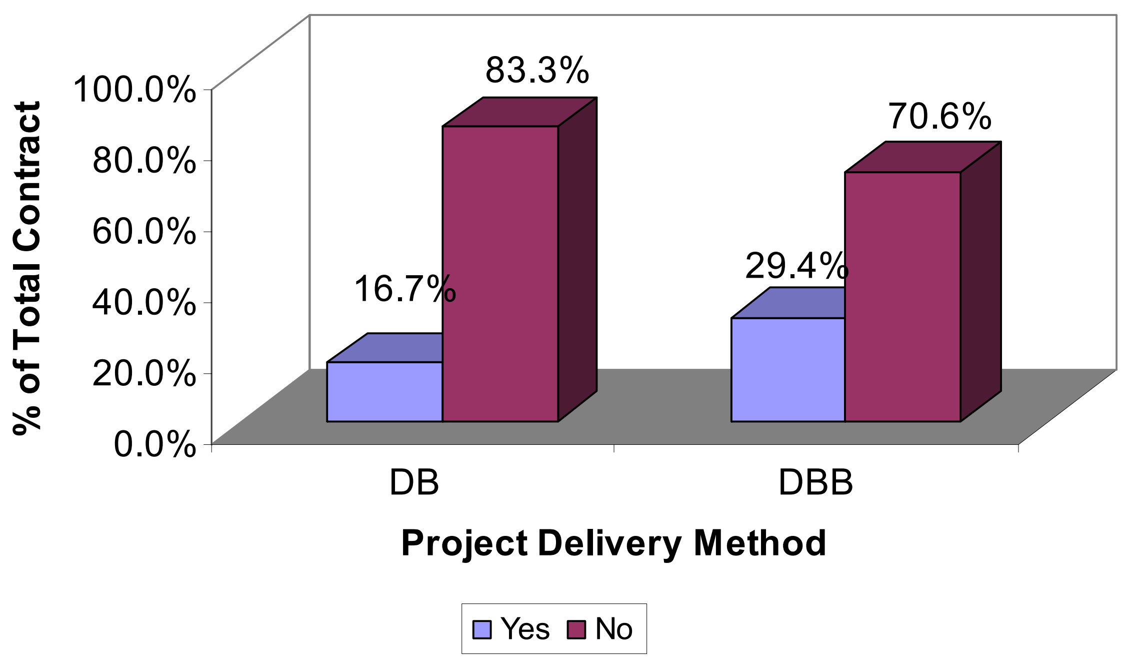


Figure A1.16: Percentage of Contract with Lane Rental Provision

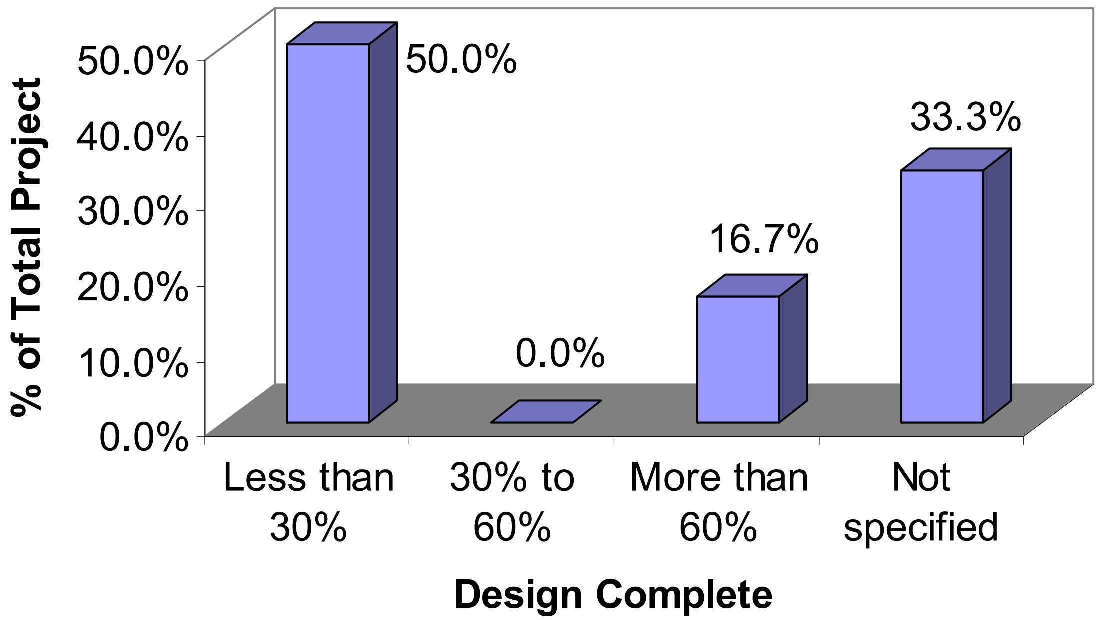


Figure A1.17: Percentage of DB Projects by Percentage of Design Completed at Contract Award Time

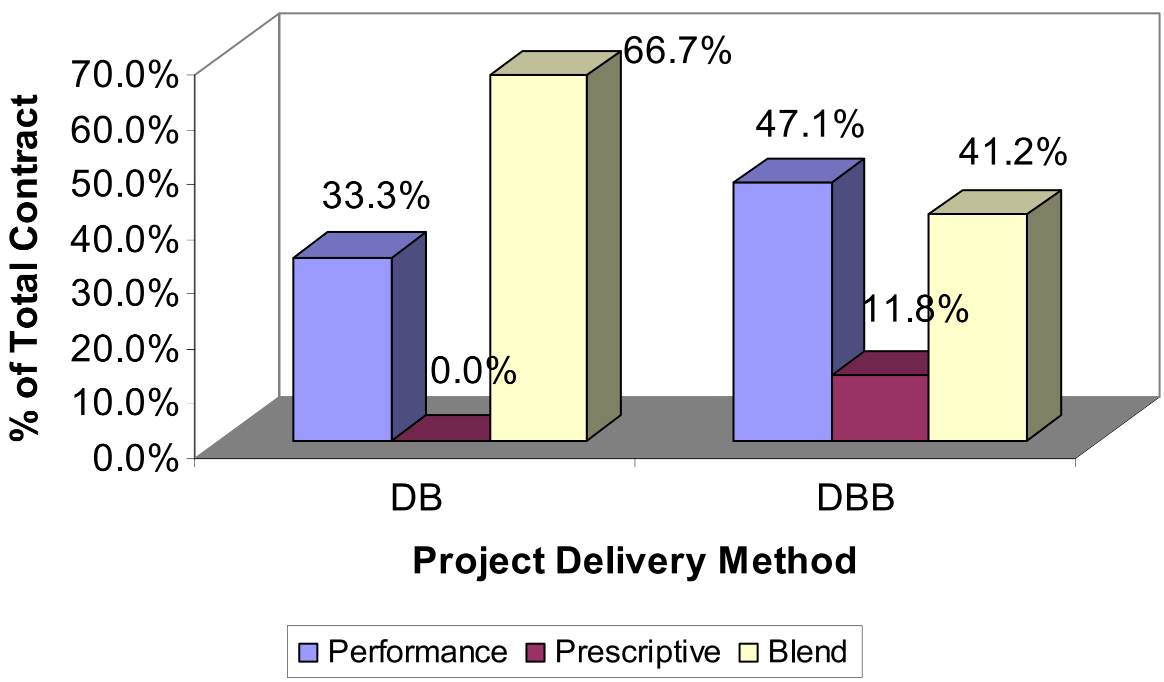


Figure A1.18: Percentage of Contracts by Type of Specification Used

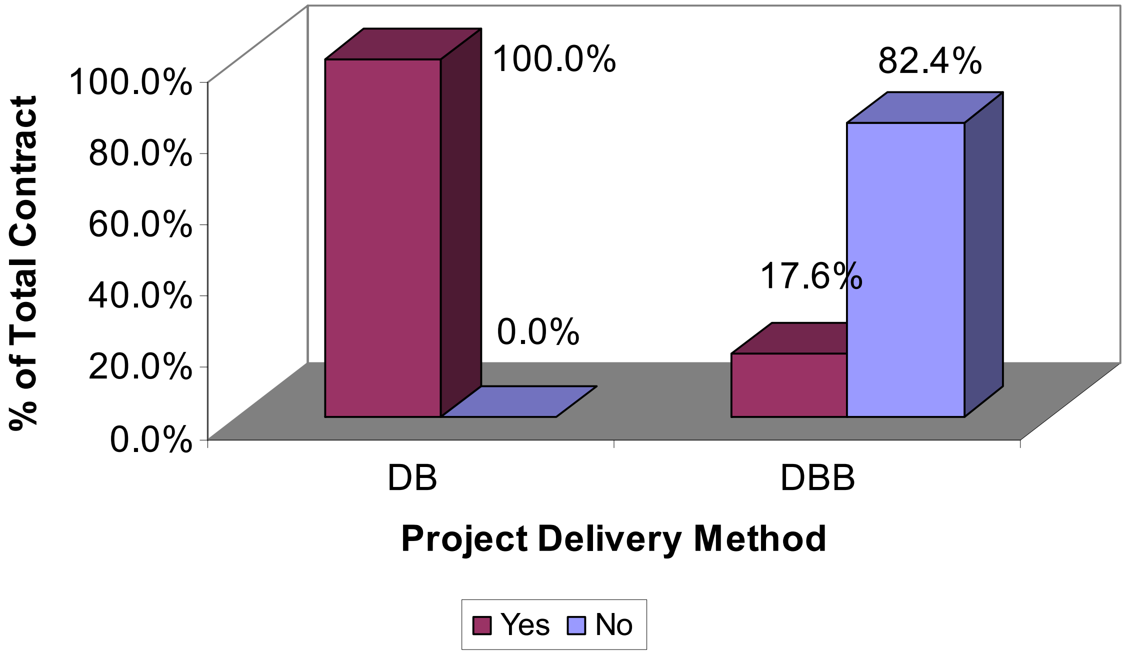


Figure A1.19: Percentage of Contracts with Partnering Consultant Involved

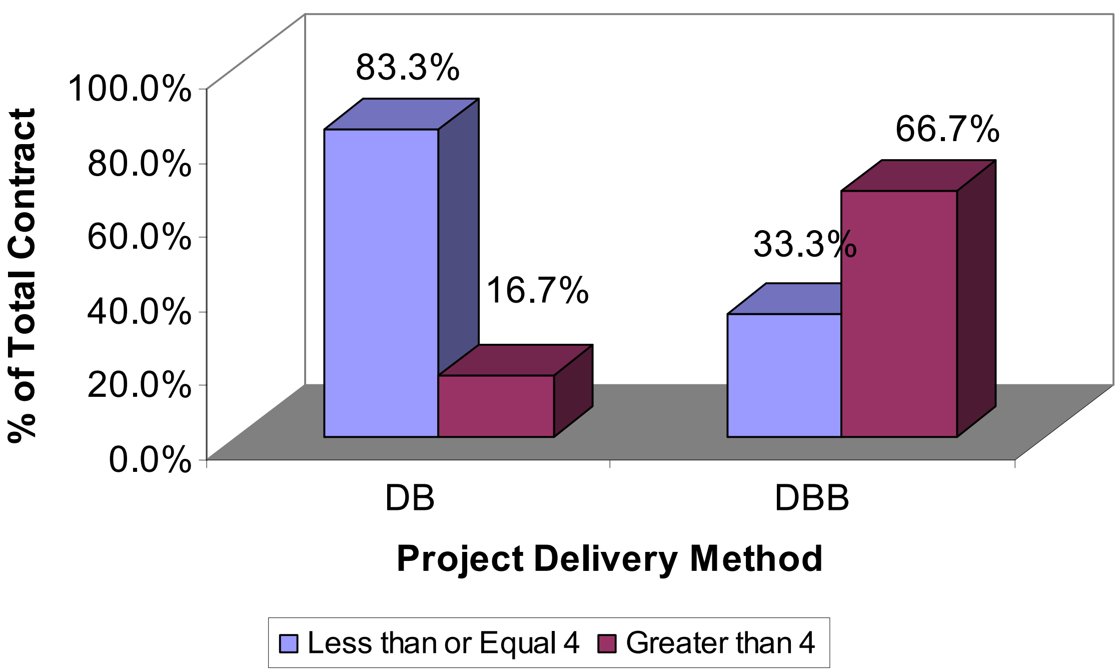


Figure A1.20: Percentage of Contracts by Yearly Partnering Meetings

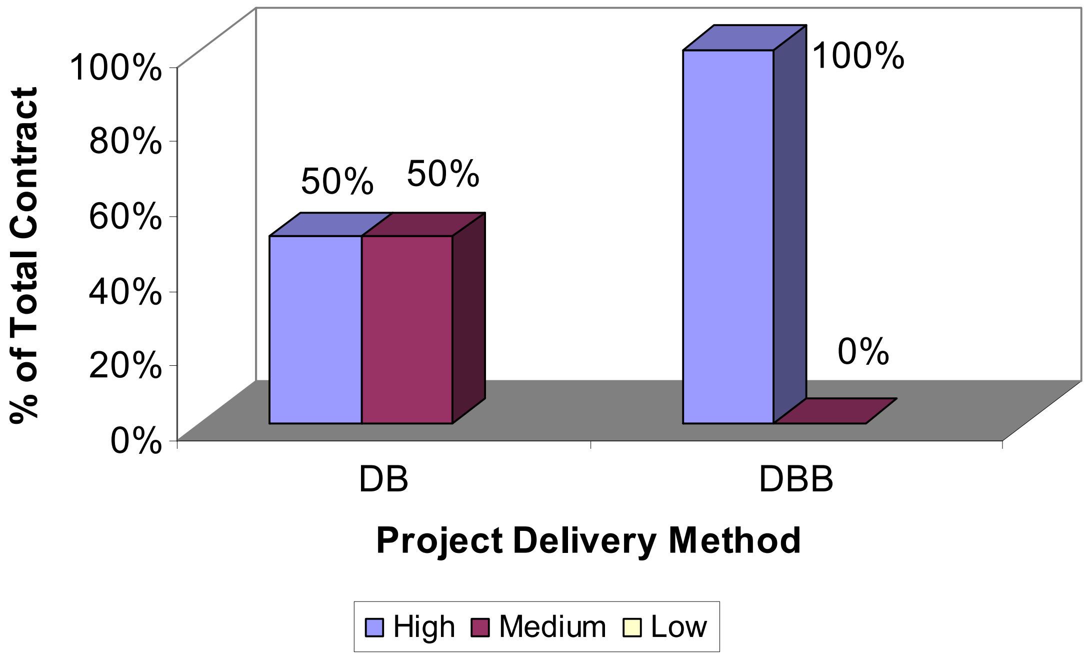


Figure A1.21: Percentage of Contracts by Environmental Assessment Level

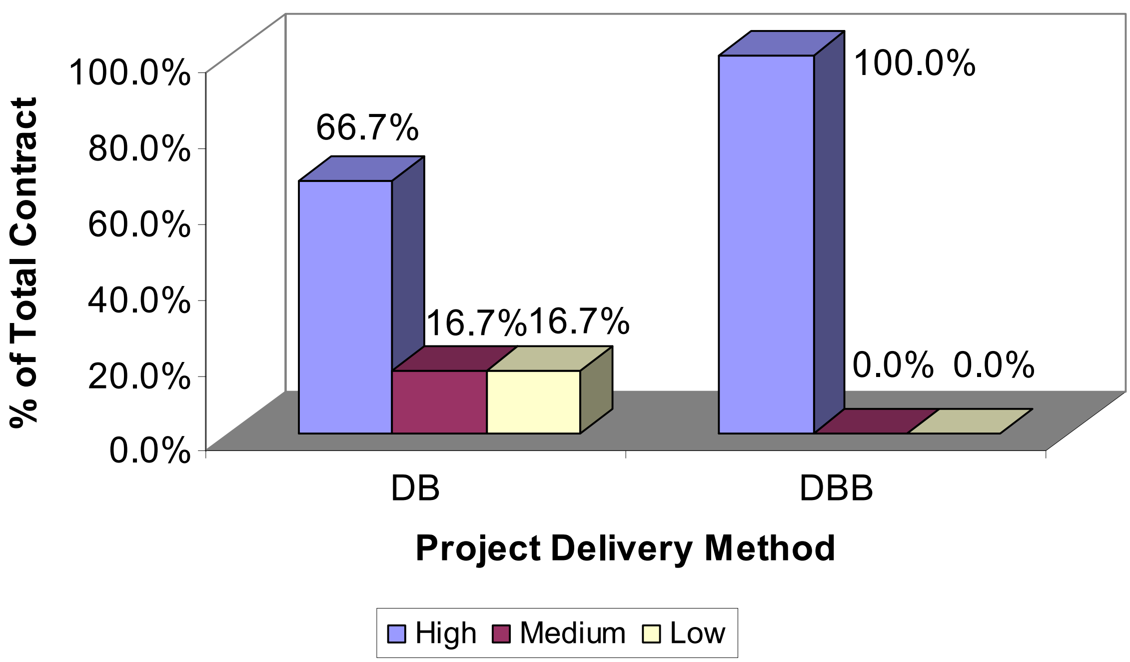


Figure A1.22: Percentage of Contracts by ROW Assessment Level

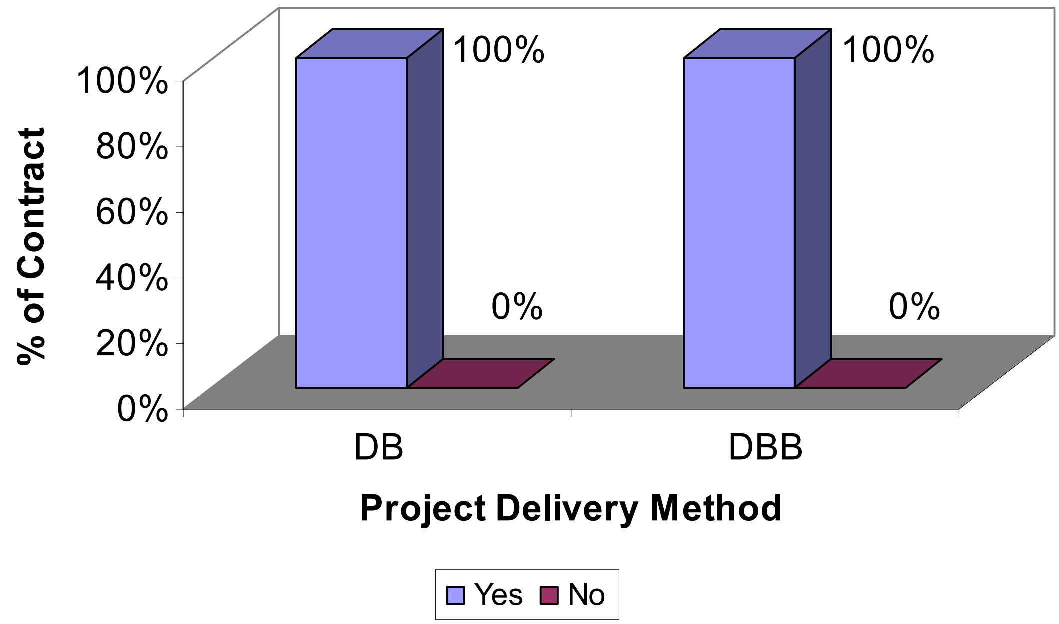


Figure A1.23: Percentage of Contracts with Owner and Contractor Co-located

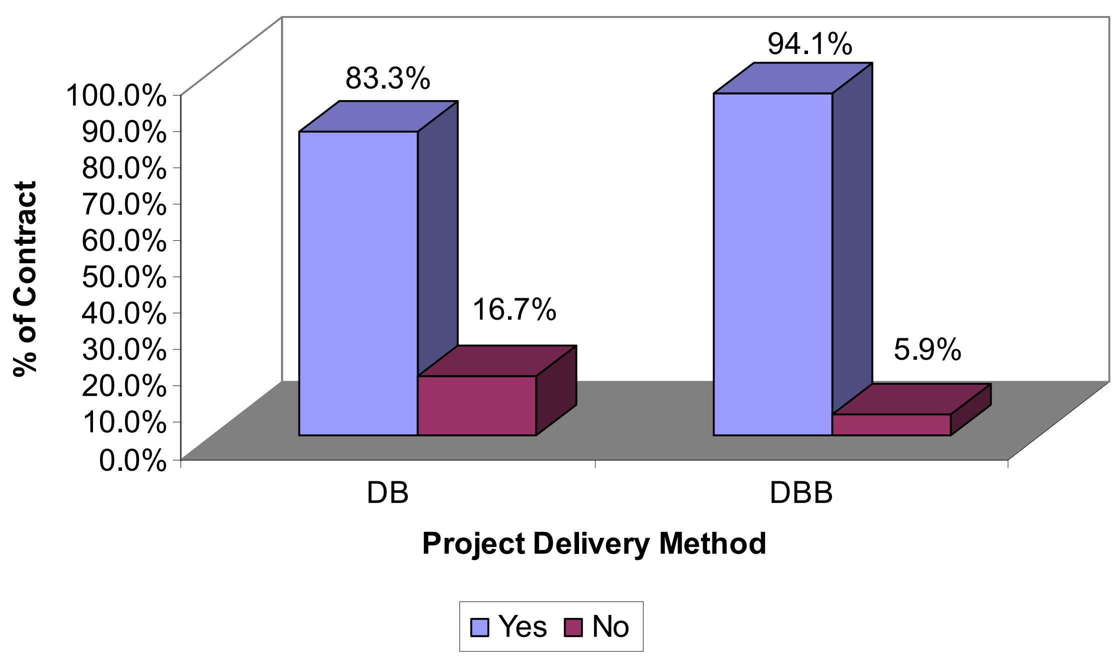


Figure A1.24: Percentage of Contracts by Formal Change Management Process

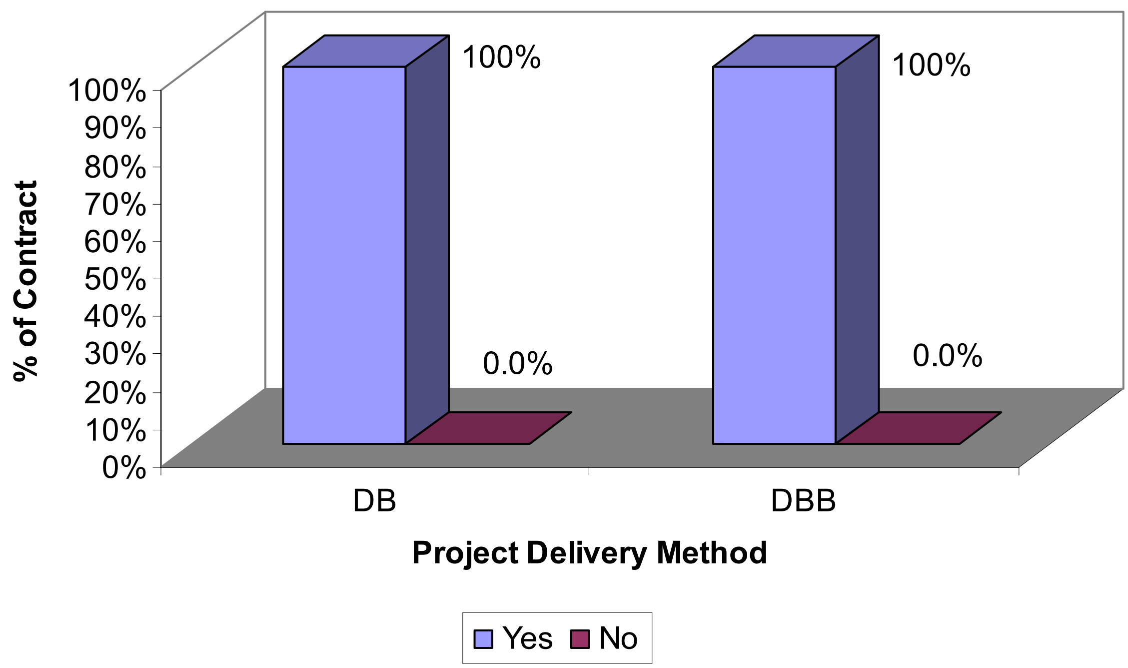


Figure A1.25: Percentage of Contracts by Constructability Process Use

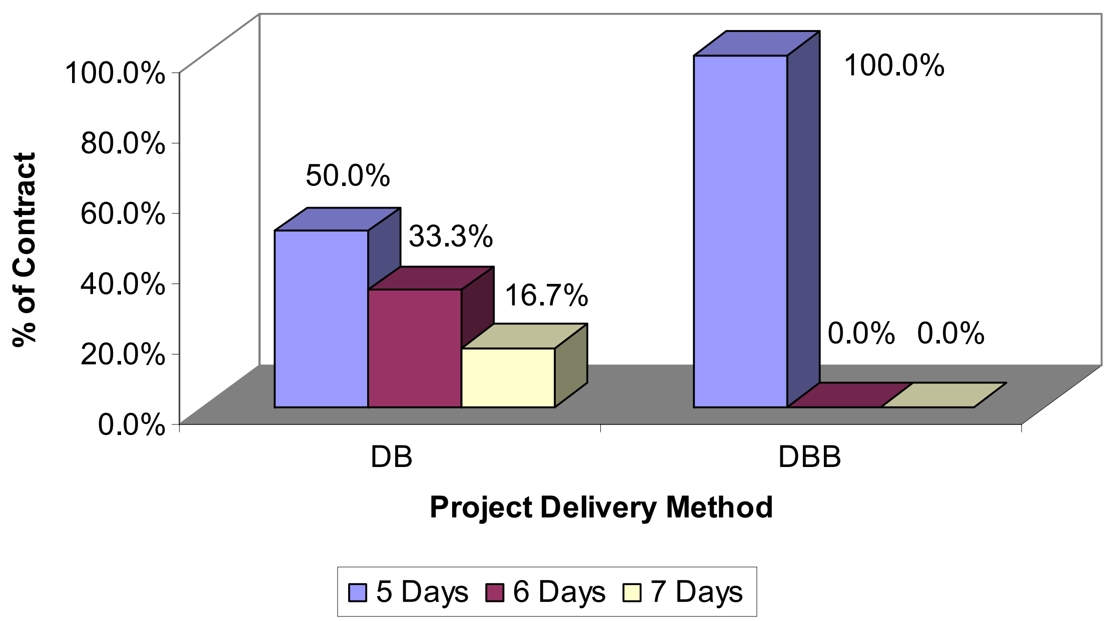


Figure A1.26: Percentage of Contracts by Design Work Days per Week

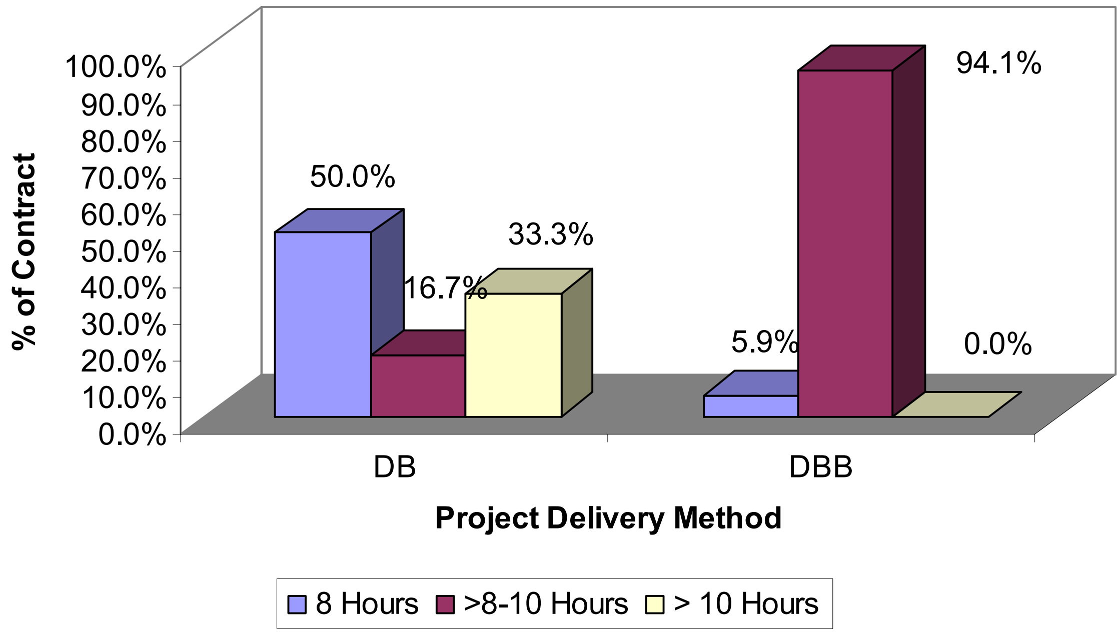


Figure A1.27: Percentage of Contracts by Design Hours per Day

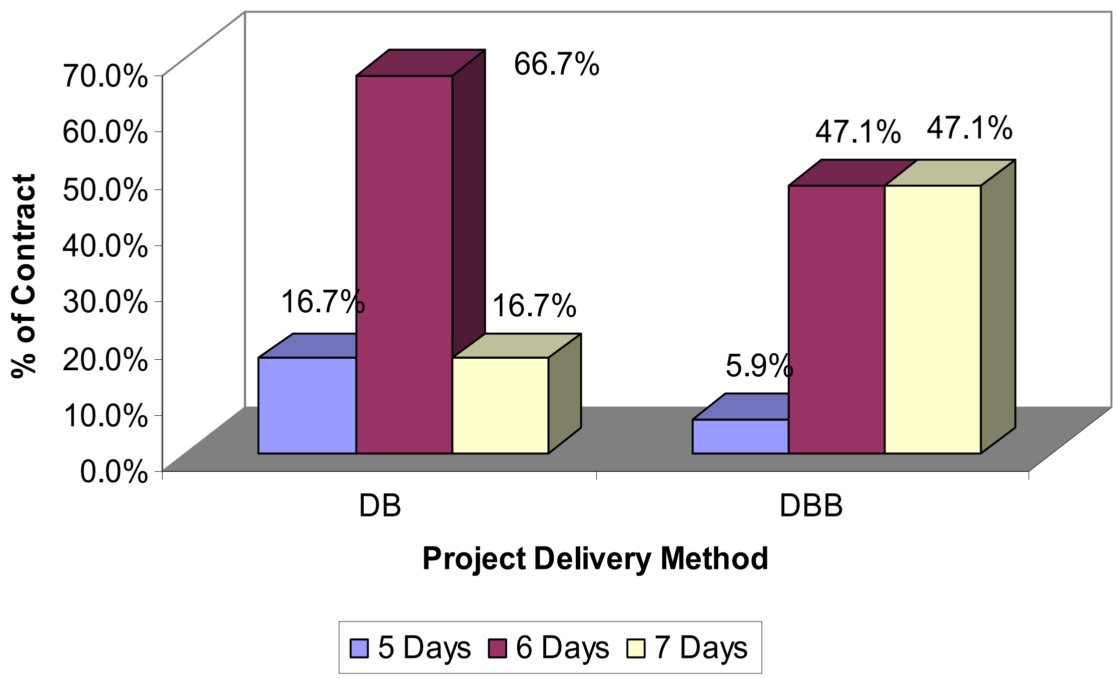


Figure A1.28: Percentage of Contracts by Construction Work Days per Week

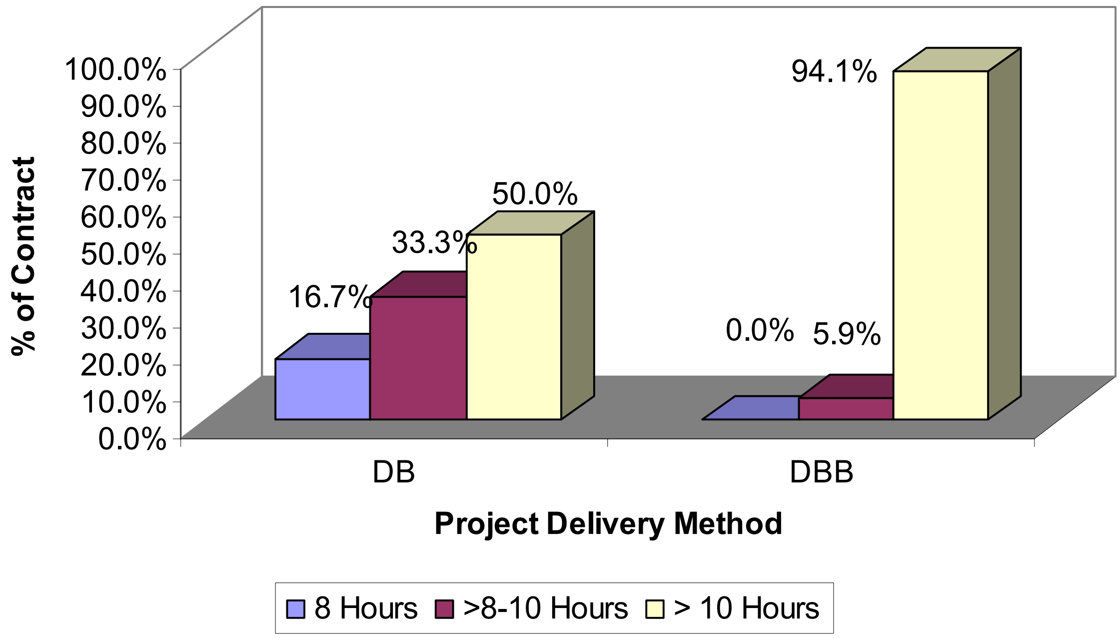


Figure A1.29: Percentage of Contracts by Construction Hours per Day

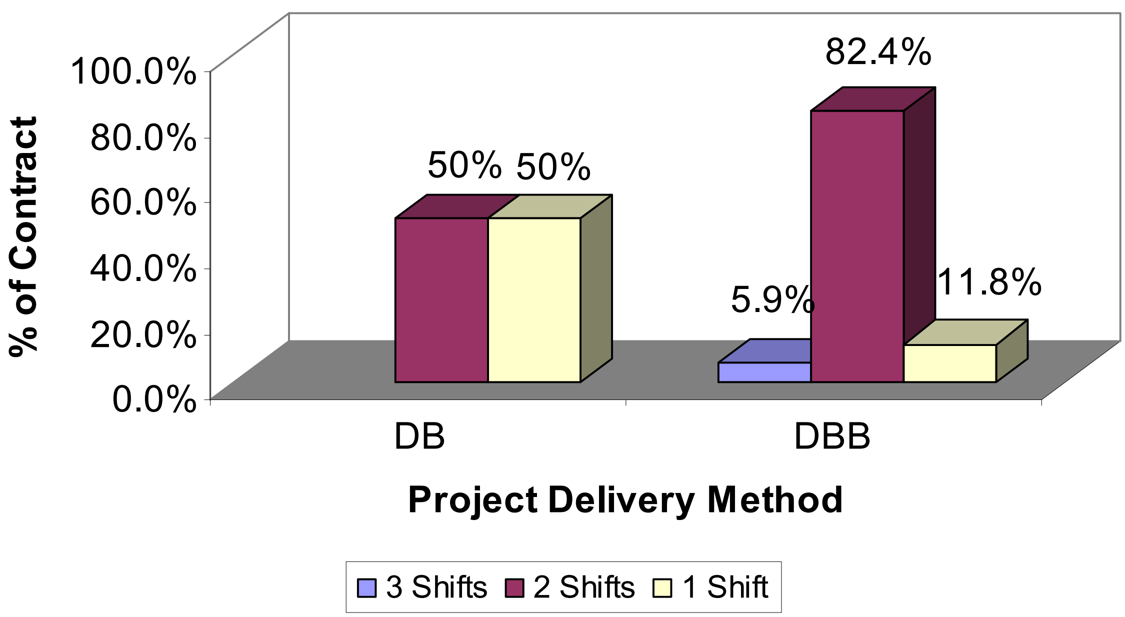


Figure A1.30: Percentage of Contracts by Construction Work Shift

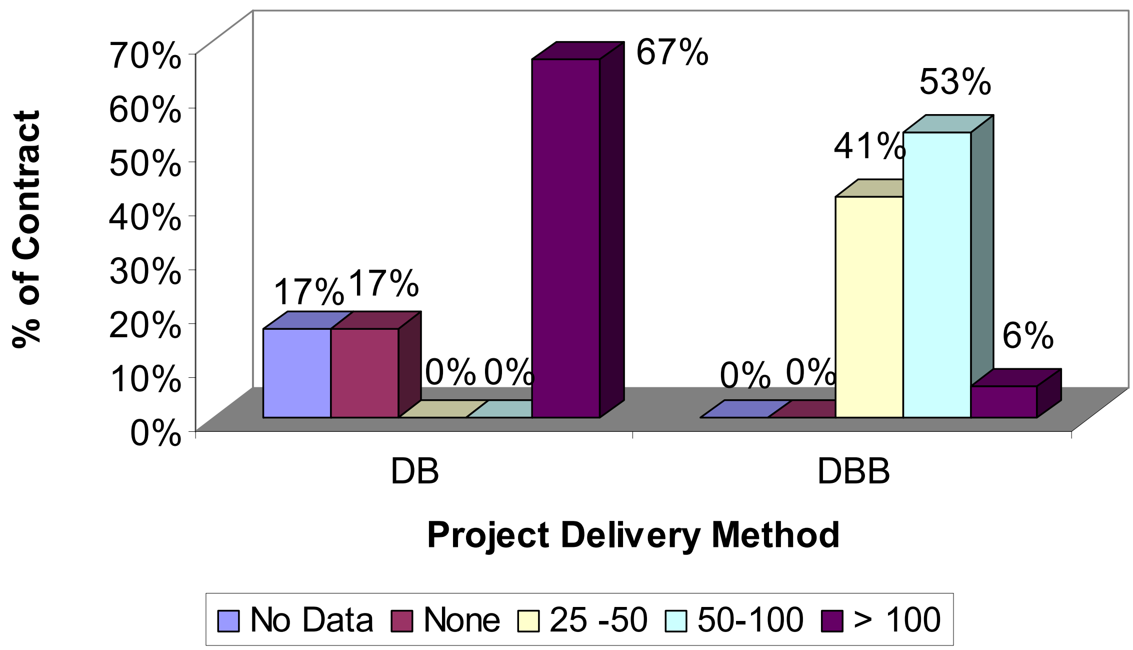


Figure A1.31: Percentage of Contracts by Total Number of ROW Parcel Procured for Construction

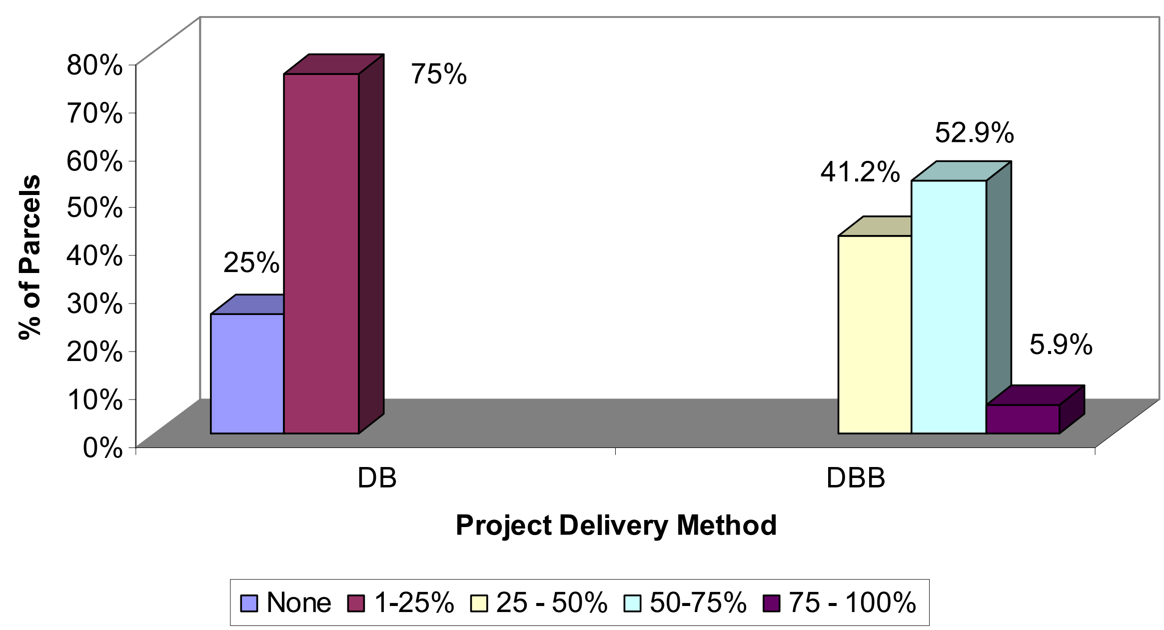


Figure A1.32: Percentage of Contracts by ROW Acquired by Condemnation

Appendix A2. Benchmarking Data: Design-Build Projects Timeline

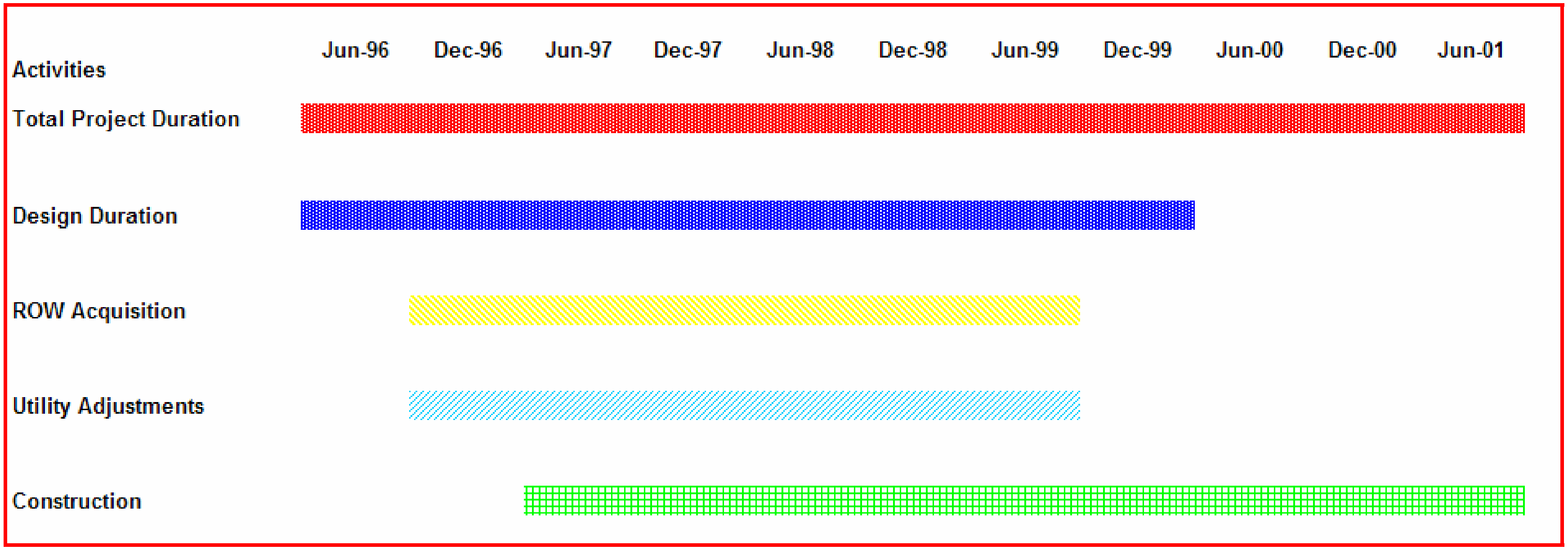


Figure A2.1 Utah I-15 Project

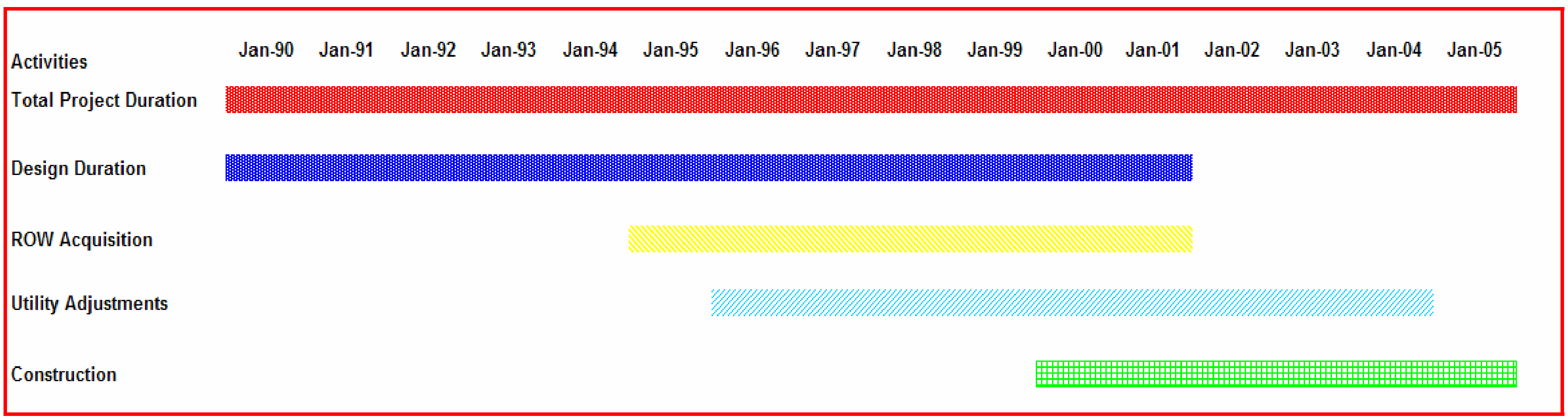


Figure A2.2 Virginia Route-288 Project

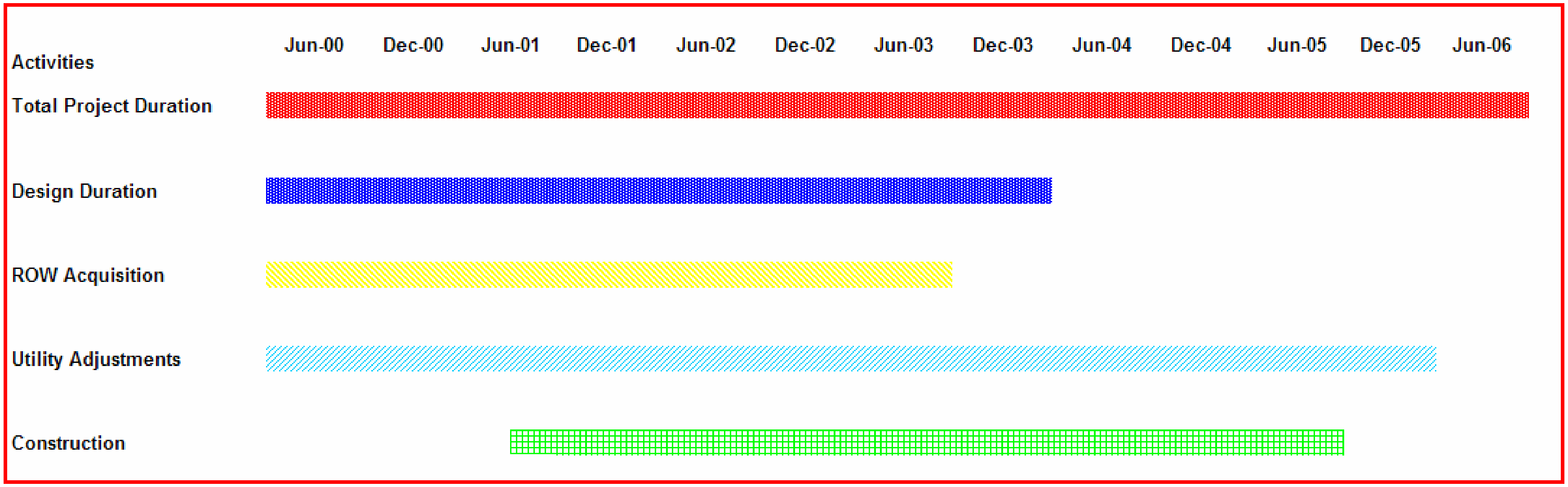


Figure A2.3 Massachusetts Route-3 North Project

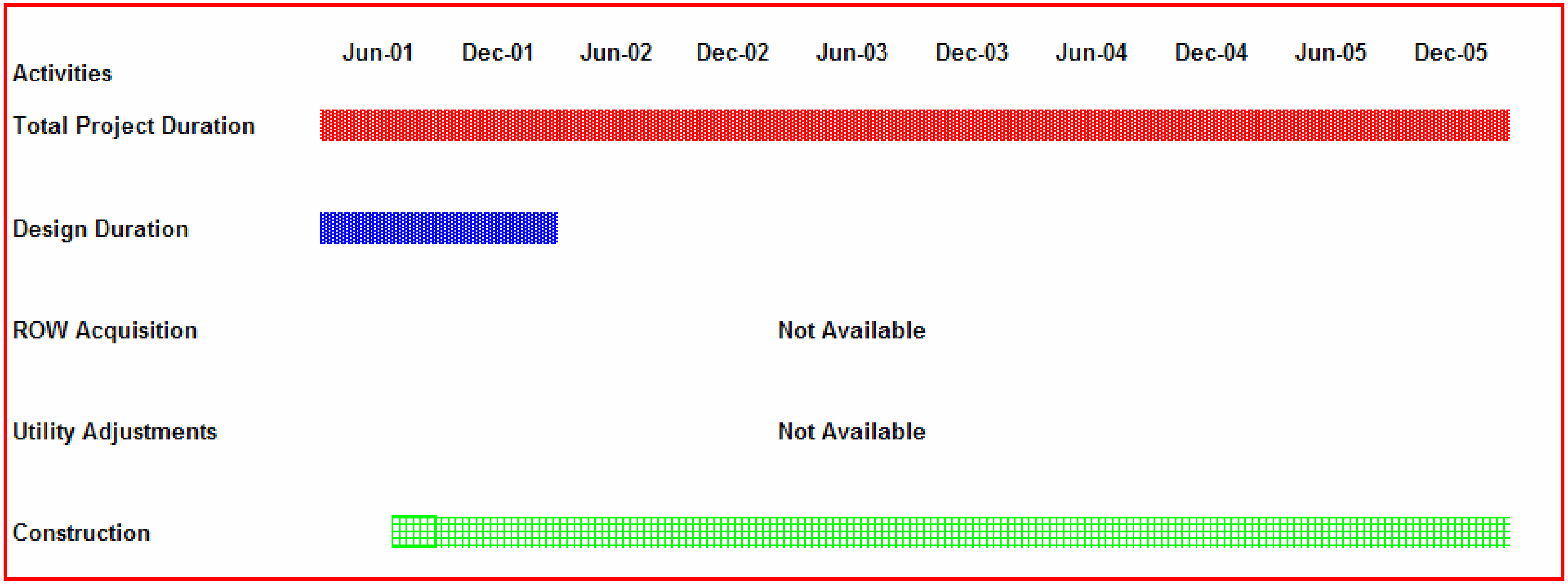
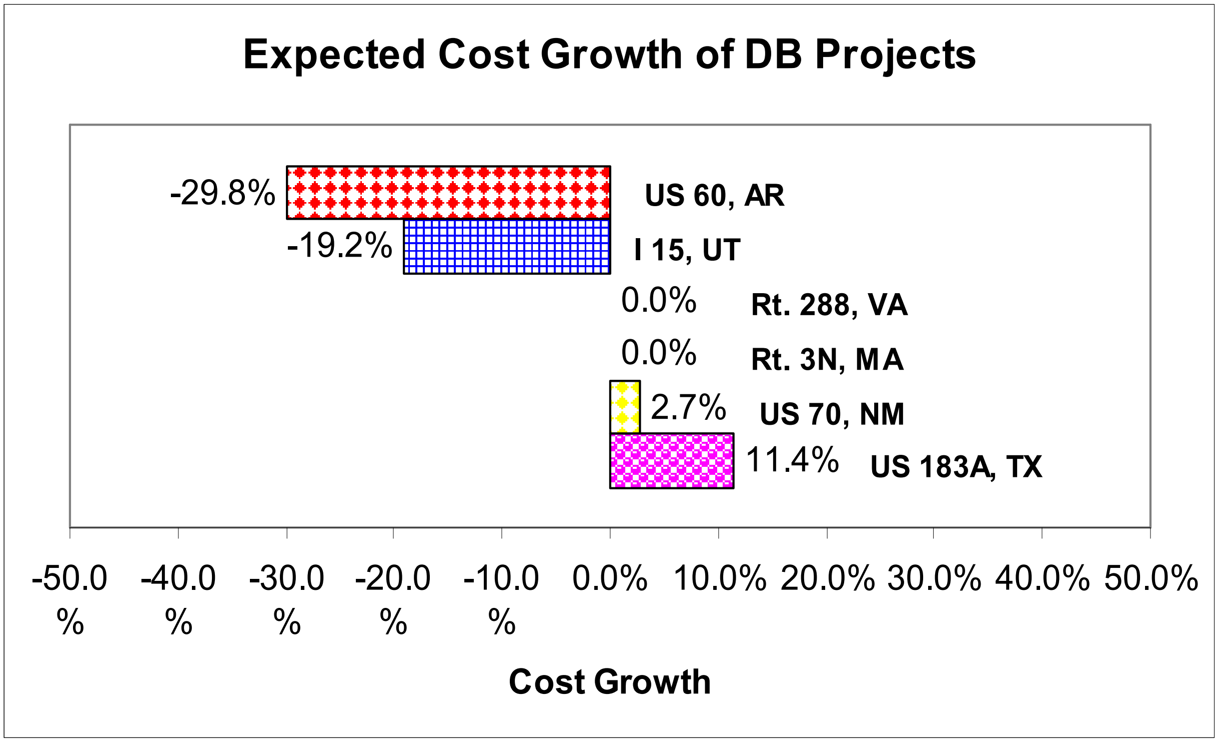


Figure A2.4 Arizona US-60 Project

Appendix A3. Benchmarking Data: Output Analysis



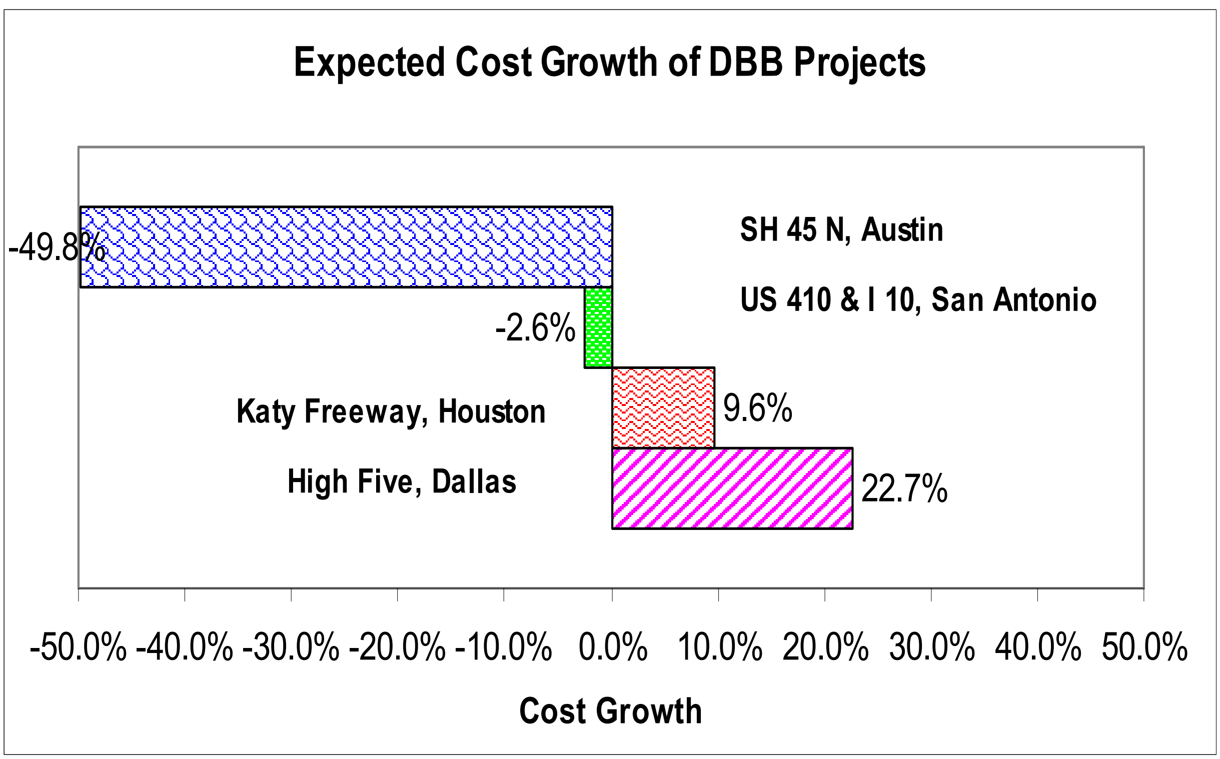


Figure A3.1: Expected Cost Growth Comparison

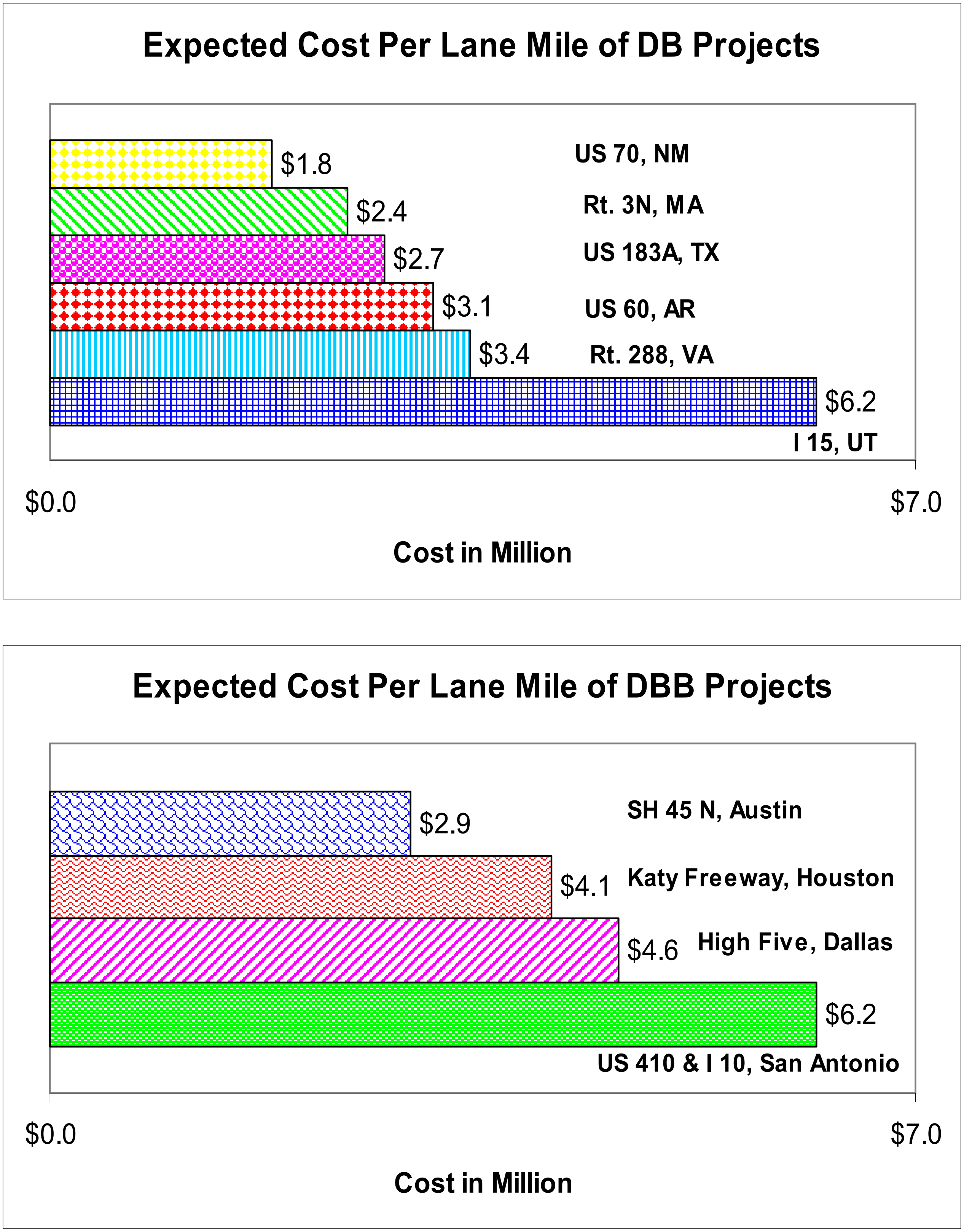
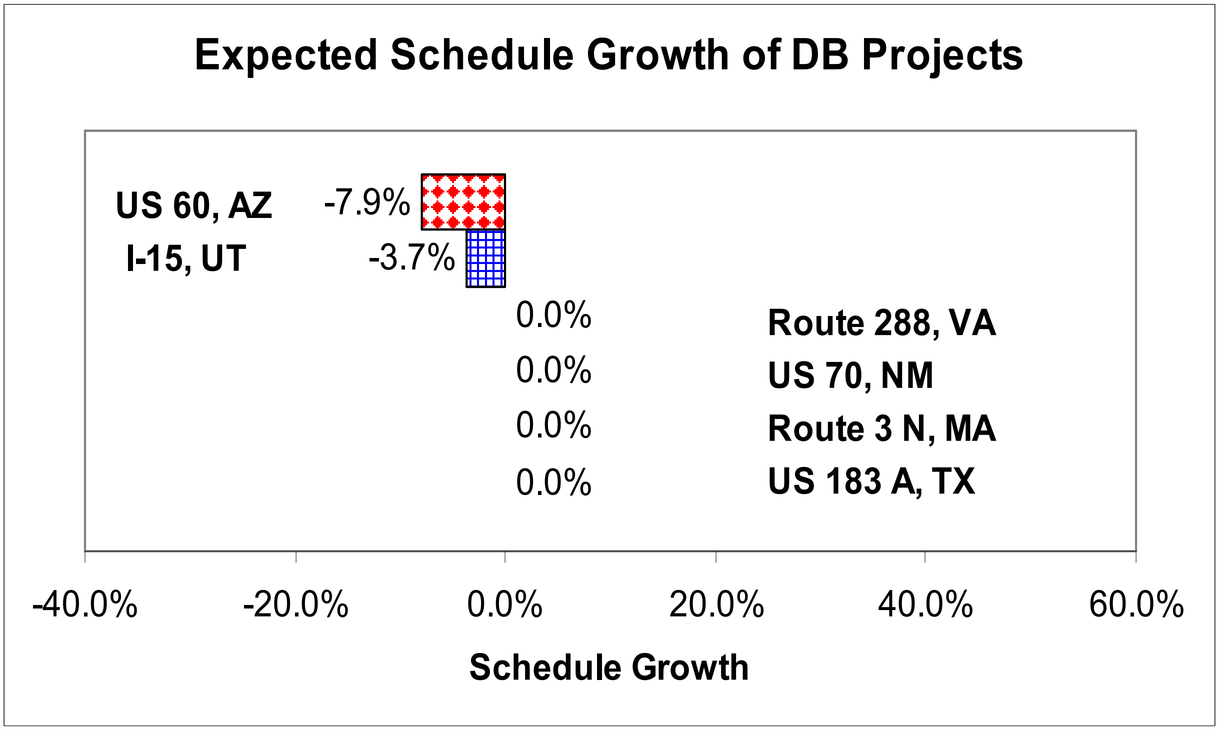


Figure A3.2: Expected Cost per Lane Mile Comparison



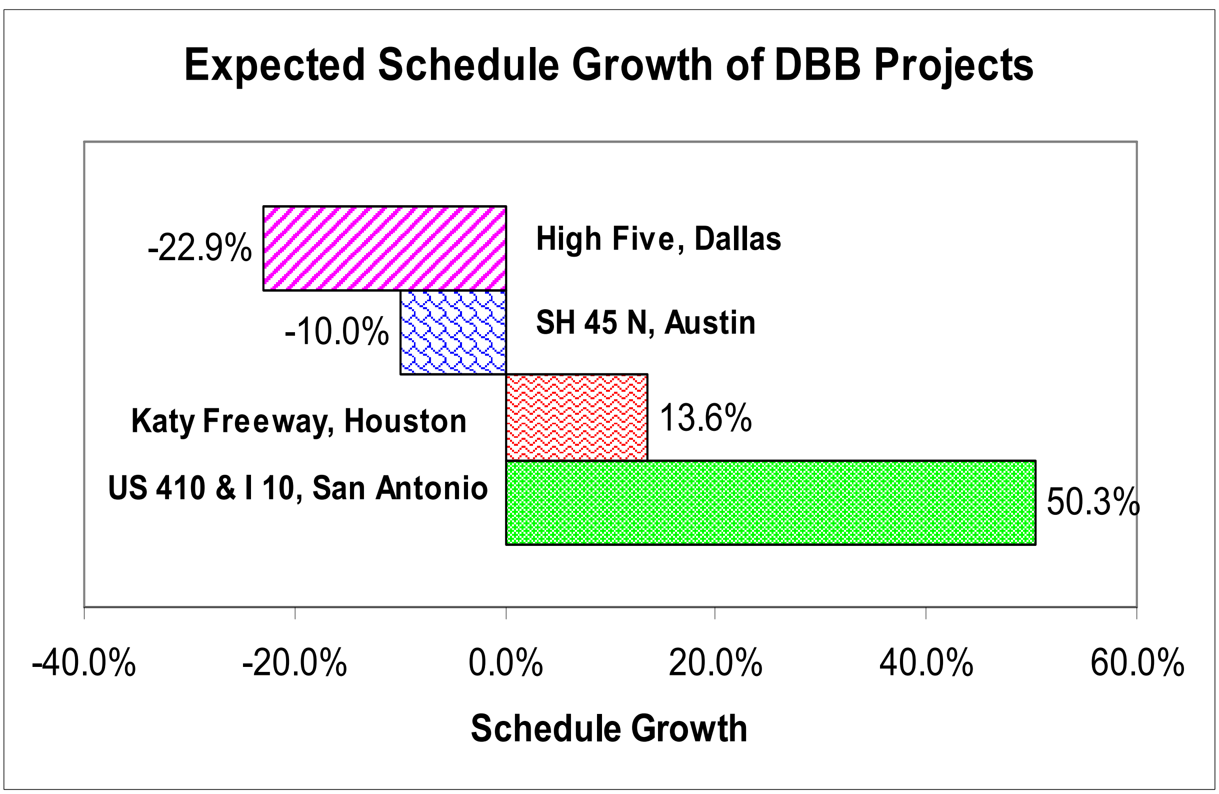
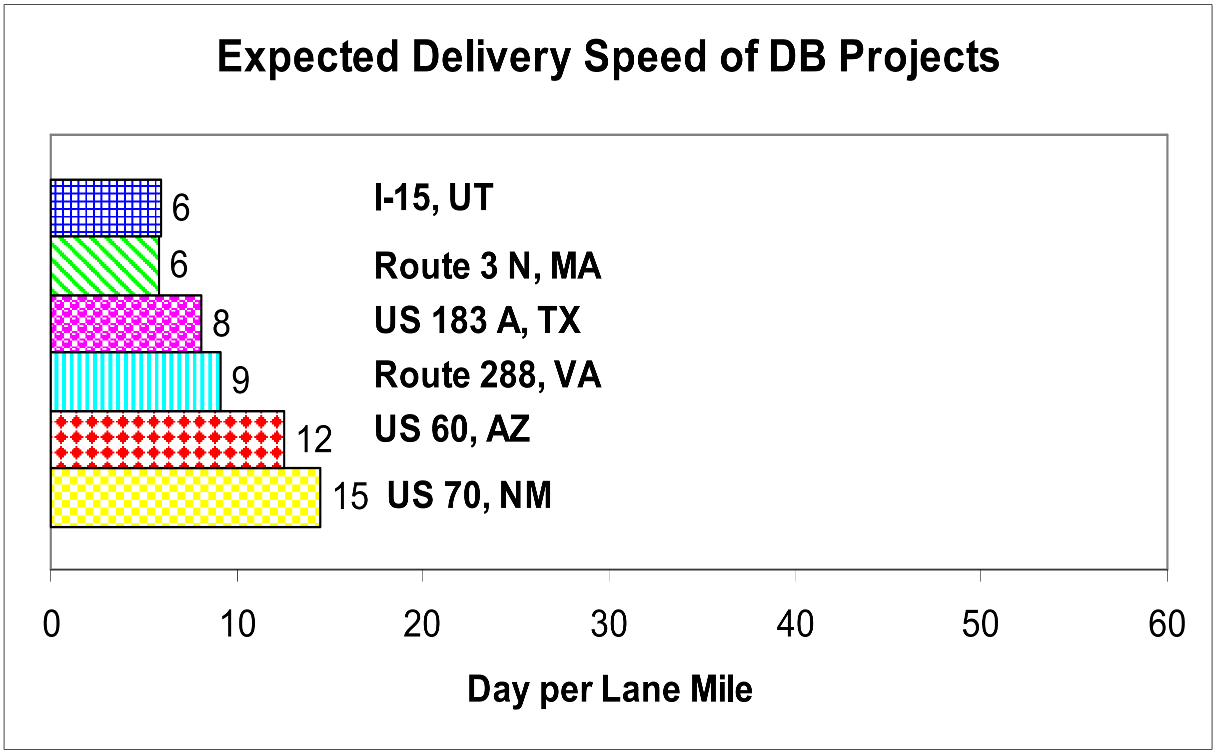


Figure A3.3: Expected Schedule Growth Comparison



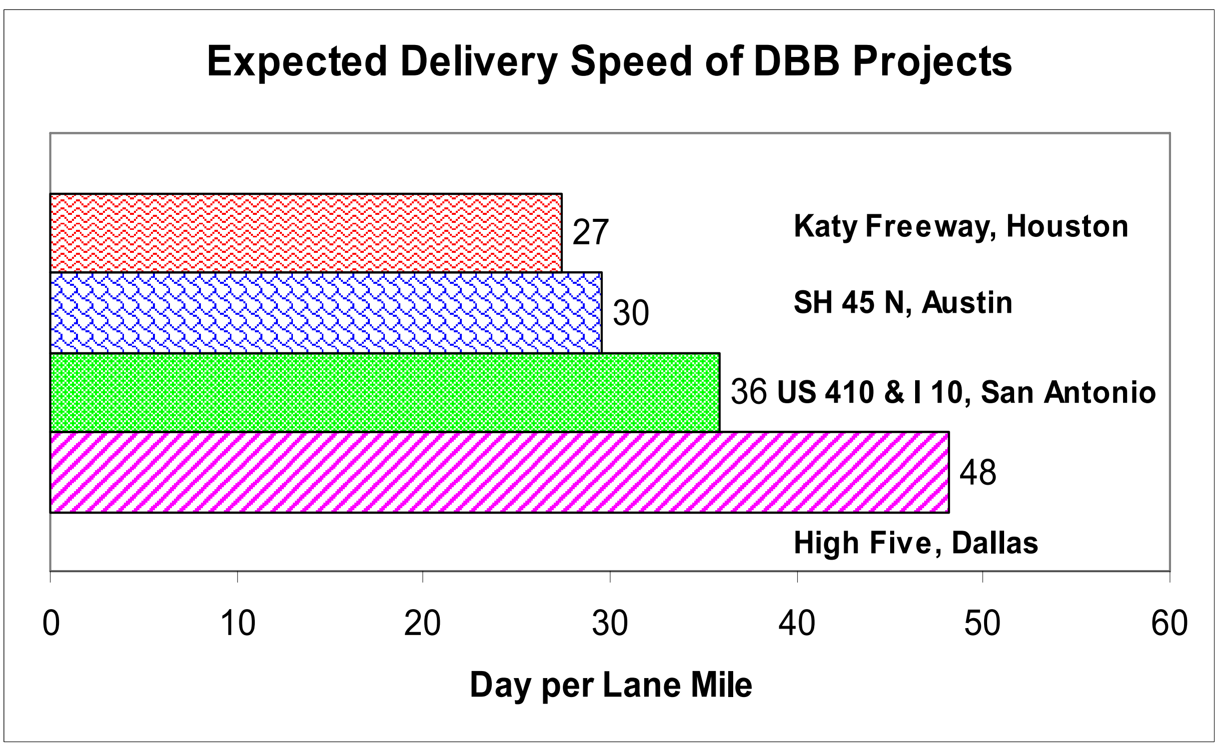


Figure A3.4: Expected Delivery Speed Comparison

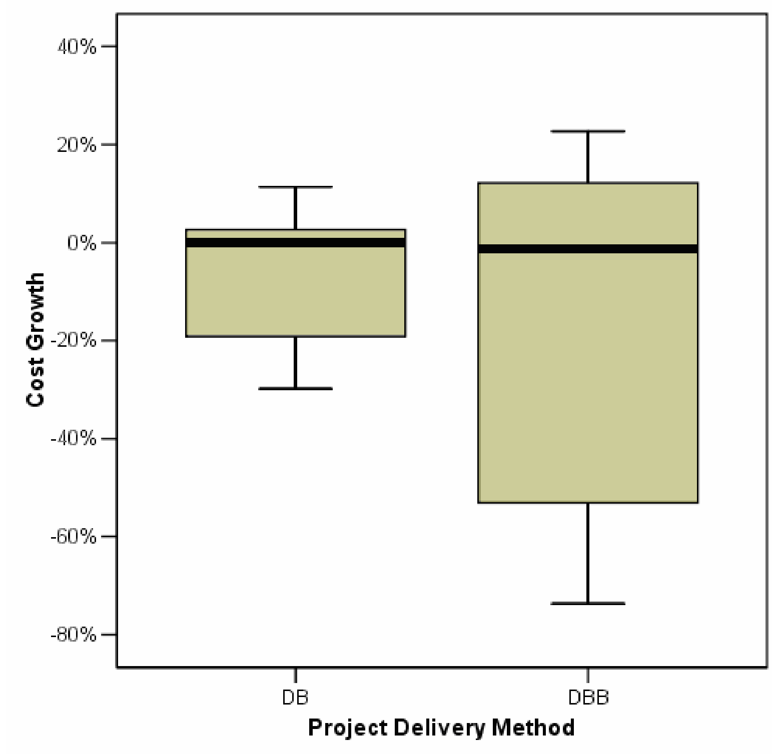


Figure A3.5: Box Plot of Mean Cost Growth

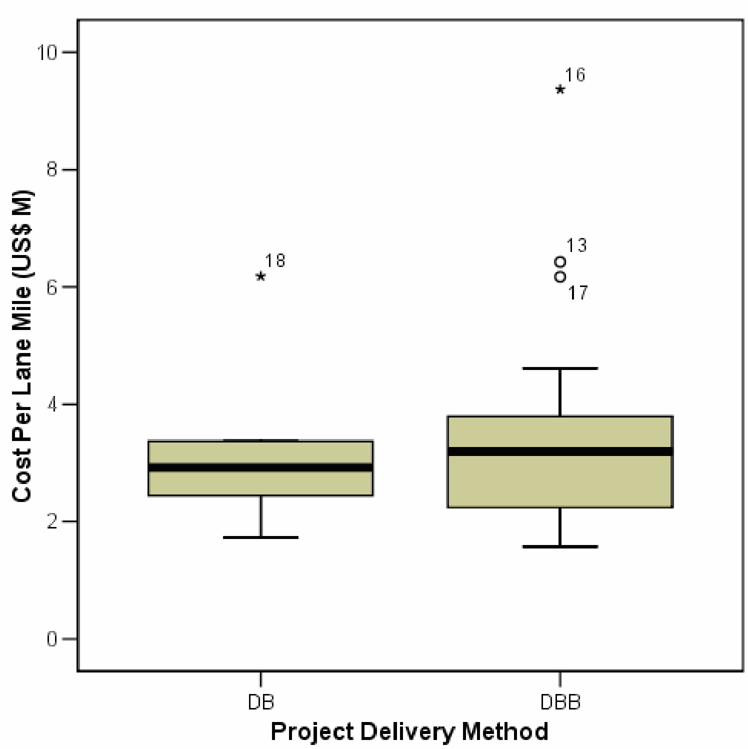


Figure A3.6: Box Plot of Mean Cost per Lane Mile

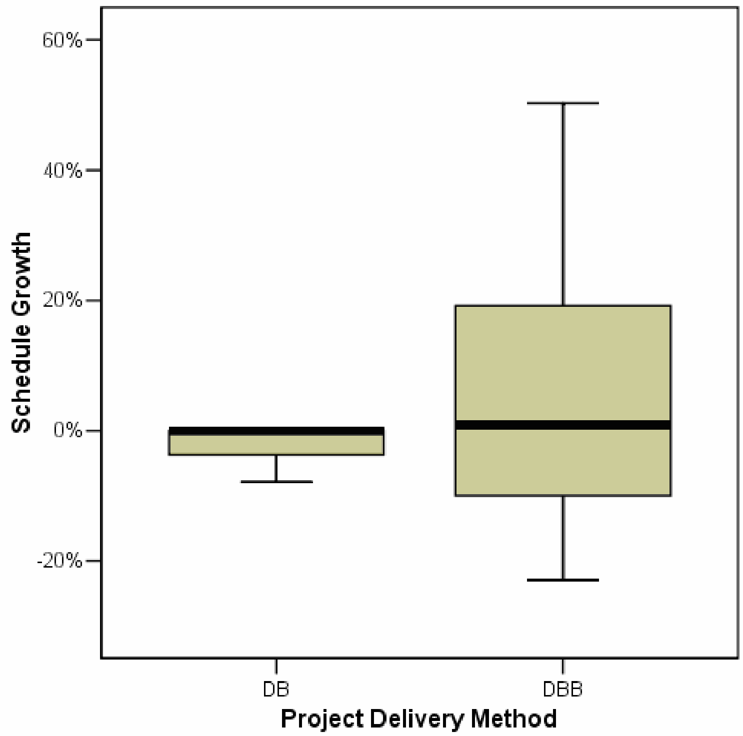


Figure A3.7: Box Plot of Mean Expected Schedule Growth

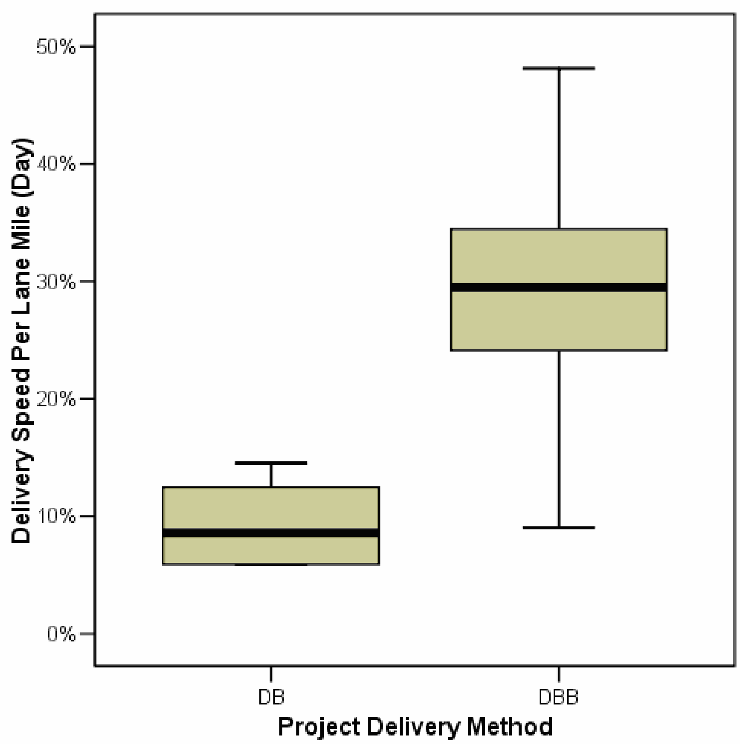


Figure A3.8: Box Plot of Mean Delivery Speed per Lane Mile

Appendix B. TxDOT SH-130 Lessons Learned System User Guide

B.1 Navigating the System

When the user opens the TxDOT SH-130 Lessons Learned System file, the main page is displayed. The main page, illustrated in Figure B.1, details the persons involved in developing the system and offers the user three options. By selecting “Enter System,” the user is immediately taken to the system’s main menu where he or she can then choose from the various features and tools of the database. The “User Guide” button links users to a page with guidelines for properly using the database. Finally, by selecting “Exit System” the entire program is immediately shut down.

Figure B.1: TxDOT SH-130 Lessons Learned System Main Page

B.2 Menu Bar

During the operation of the system, a menu bar is continuously displayed in the top left corner of the screen. This can be seen in Figure B.2, where the menu bar is highlighted in the top left corner of the form. The user can select one of these options at any time and they will be immediately taken to the chosen feature. These features include, “Access Lessons Learned,” “Enter Lessons Learned,” “Enter Other Information” (phases, categories, projects, contacts), “Expert Contacts,” “User Guide”, and “Exit”. In addition to the menu bar, each form contains the option to return to the main menu or exit the system. These features allow the user to travel to any area of the system they choose at any time.

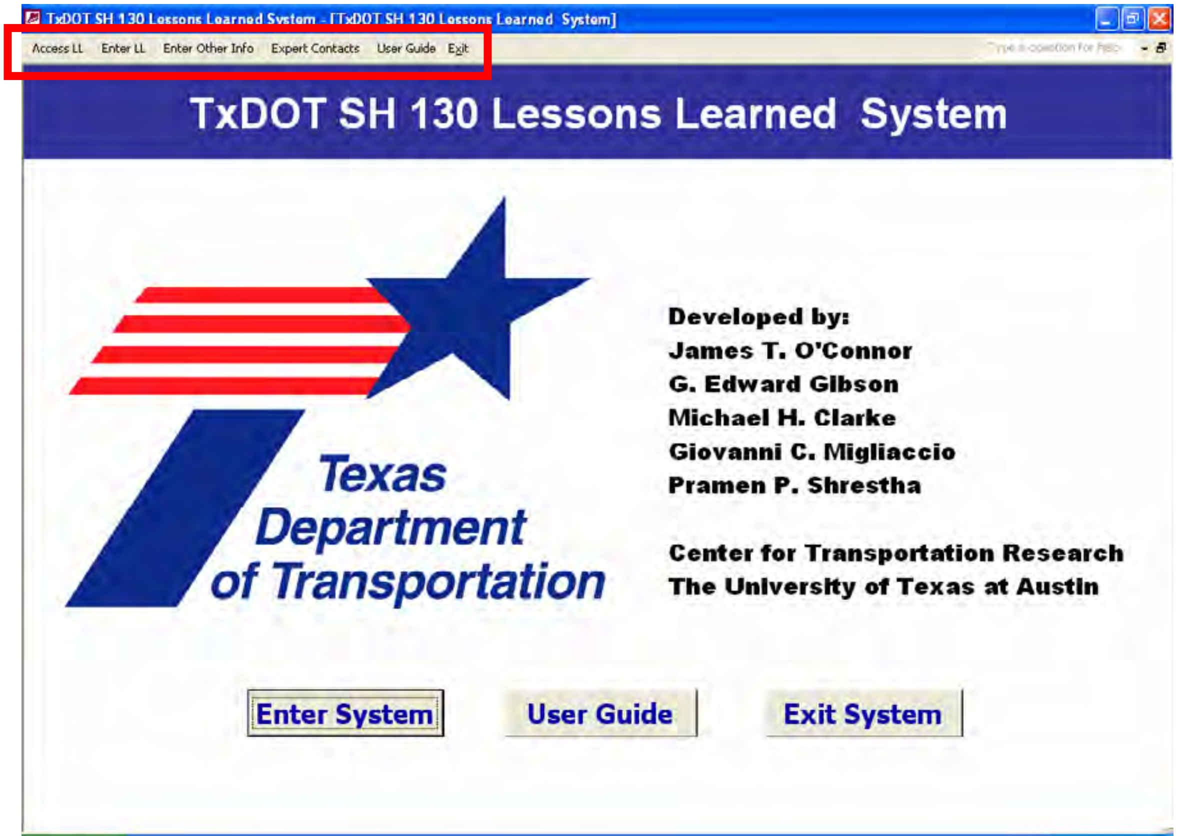


Figure B.2: System Menu Bar

B.3 Main Menu

Once the user has entered the system, he or she is presented with the main menu of the system (See Figure B.3.) Users can choose from among six options. The first option, “Access Documented Lessons Learned,” allows the user to search the database for lessons learned. Lessons can be chosen according to phase, category, or project. Another option, “Enter New Lessons Learned,” allows the user to input information into the database for any new lessons that have been identified. The “Enter New Sorting/Support Data” option provides the user with the opportunity to enter new information that is not already stored within the system, e.g. phases or projects. “View Expert Contact List” is the option that presents users with contact information for various TxDOT personnel. The “User Guide” option is helpful for anyone not familiar with the system. “Exit System” is the final option. The following sections detail the results of selecting each of the first five options.

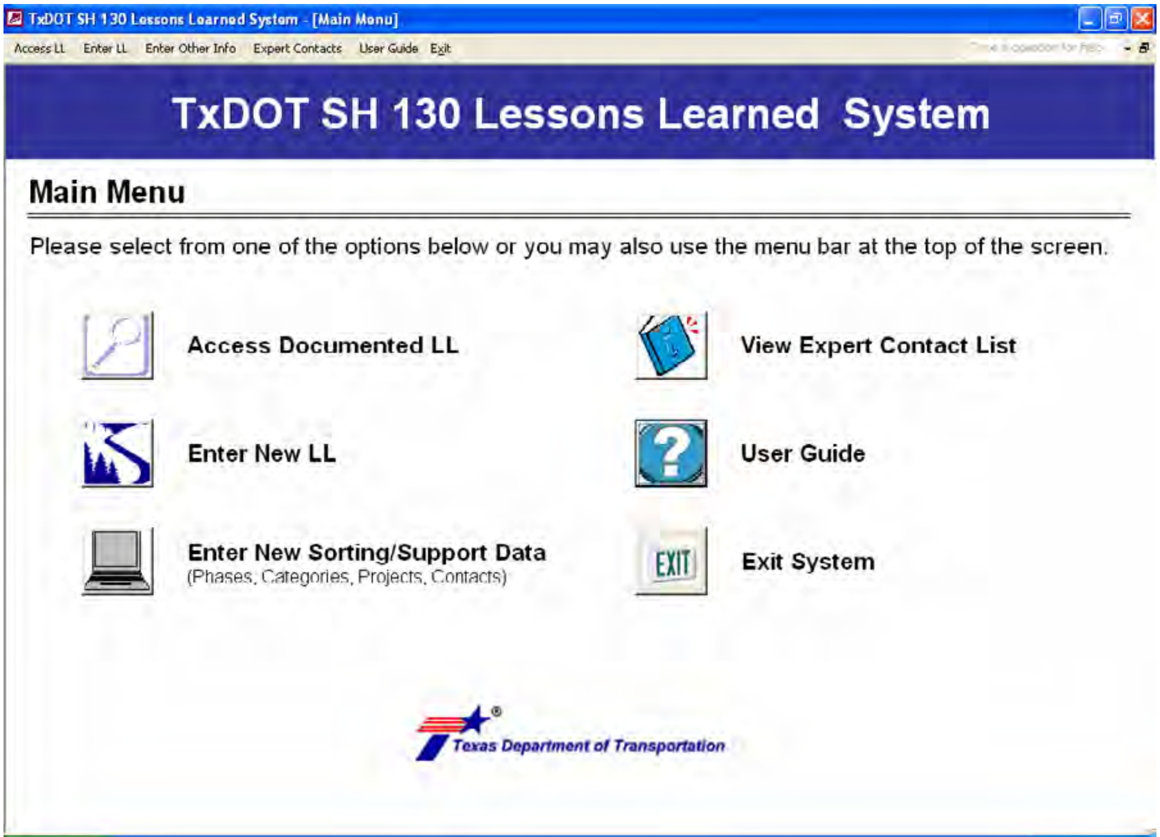


Figure B.3: Main Menu Form

B.4 Access Lessons Learned

The user can access documented lessons learned with the search menu that first appears in the lessons learned system (See Figure B.4.) There are four options within this menu; search by phase; search by category; search by project; view all documented lessons learned. The "Search by Phase" option allows the user to view lessons associated with a particular phase of the project, such as design or construction. The "Search by Category" option can be used to sort lessons learned that are related to a particular aspect of the project, such as project communication or project organization. To search lessons learned on a particular project, the "Search by Project" option must be chosen. Finally, by selecting "View All Documented Lessons Learned," the entire collection of the lessons is displayed.

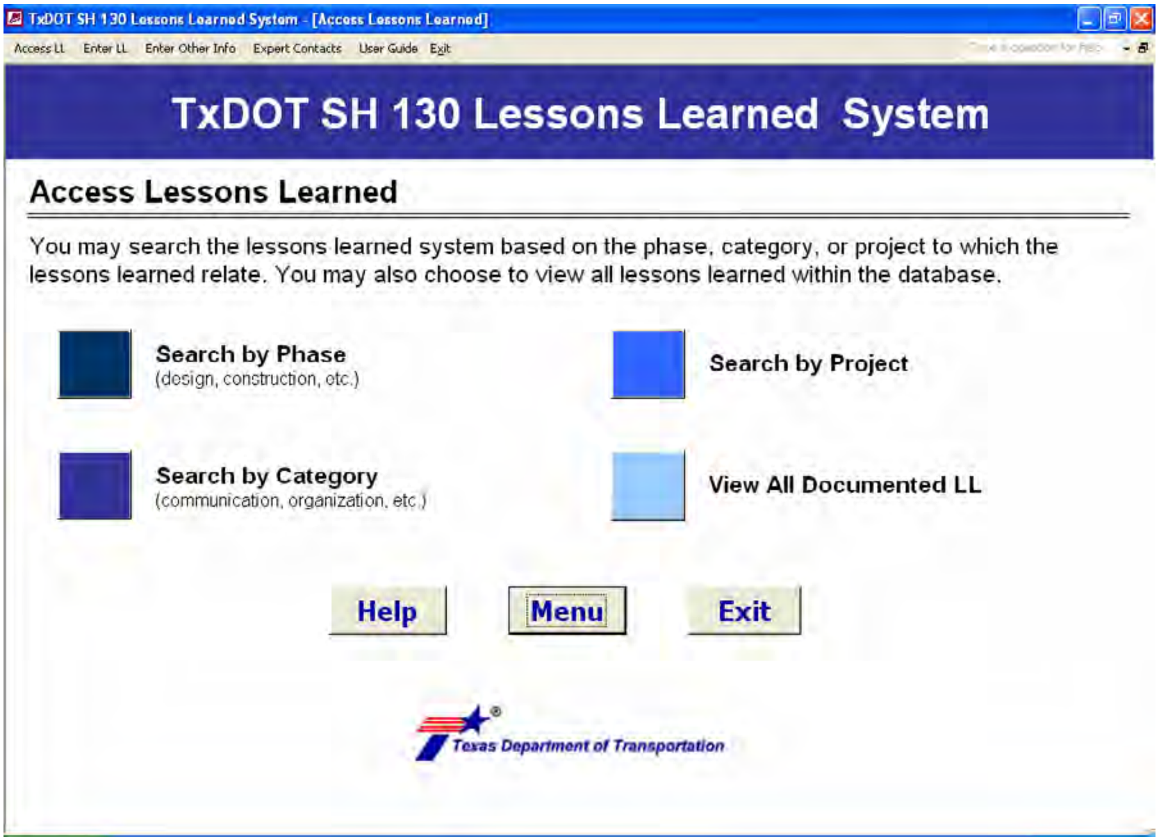


Figure B.4: Lessons Learned Search Form

After selecting one of the four options for searching lessons learned, the user is presented with a search form. For example, if the user selected the "Search by Phase" option, he or she would be presented with the form represented in Figure B.5. The user is then prompted to select a phase from a drop-down menu highlighted in the top left corner of the form. Once the user selects the desired phase, the system retrieves all lessons learned related to that particular phase. The system displays the title, context, lesson learned, impact, source, phase, category, and project of each lesson. In the sample represented in the figure, the design phase was chosen and the system assembled the thirteen lessons in the database related to design. Users may navigate through these thirteen lessons using the arrows highlighted on the bottom left corner of the form. In addition, the user can select a different phase at any time to view a new set of lessons. Finally, once the salient lesson has been located, the user can choose to print it, return to the main menu, or exit the system.

The other search options, "Search by Category" and "Search by Project," are identical to "Search by Phase" except rather than choosing the phase, the user is prompted to choose the category or project to find the desired lessons learned.

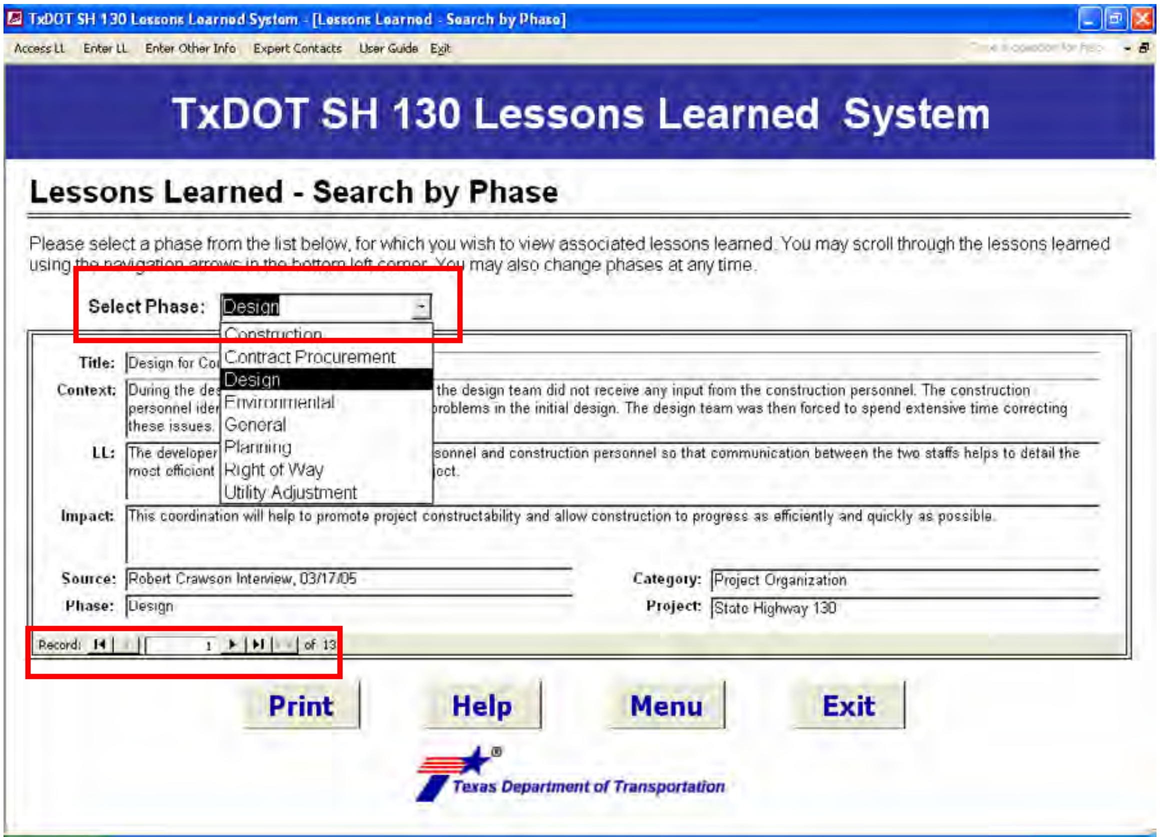


Figure B.5: Lessons Learned—Search by Phase Form

Figure B.6 shows a typical lessons-learned report. The report presents the lessons that were displayed on the screen at the moment the "Print" option was selected. For example, if the user is viewing lessons related to design then the report will included only lessons related to design.

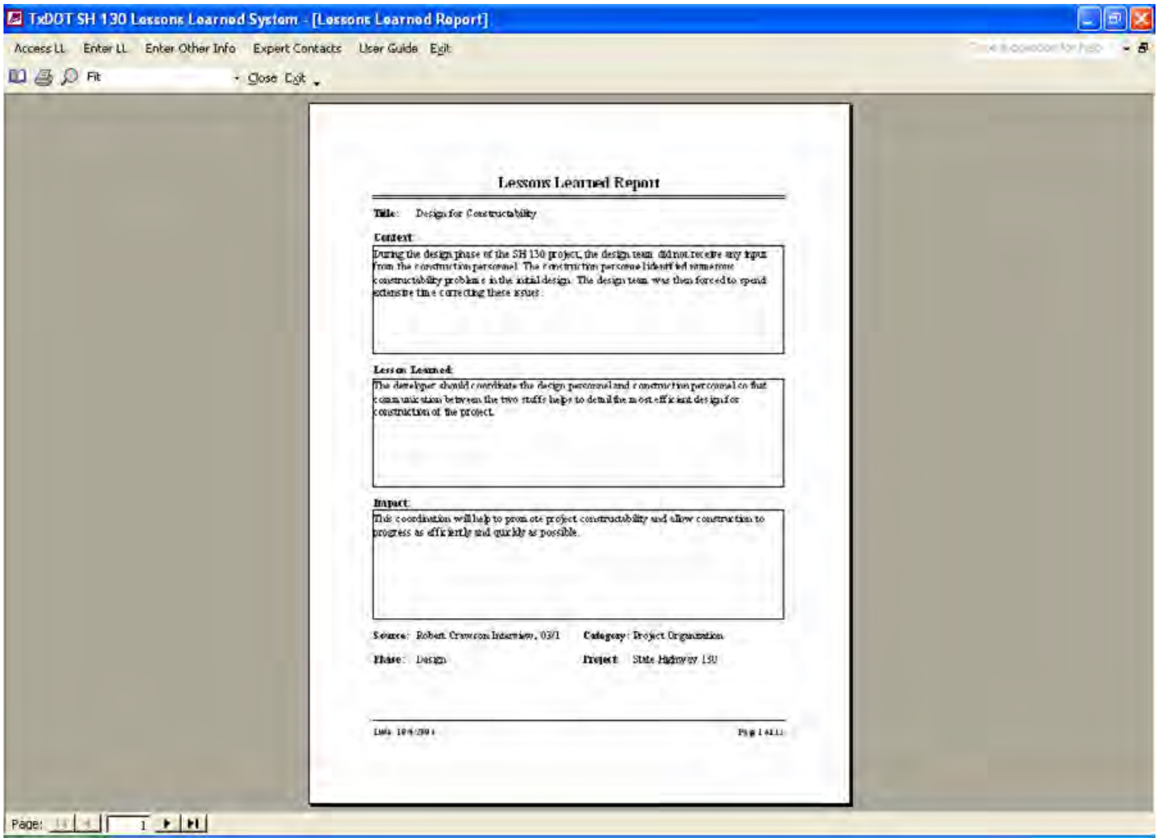


Figure B.6: Lessons Learned Report

B.5 Expert Contact List

If the user selects the "Expert Contact List" feature, they are immediately taken to the tabular list shown in Figure B.7. The table straightforwardly presents each expert's name, area of expertise, telephone number, email address, and mailing address. Once the user has finished viewing the list he or she can choose to print the list, return to the main menu, or exit the system.

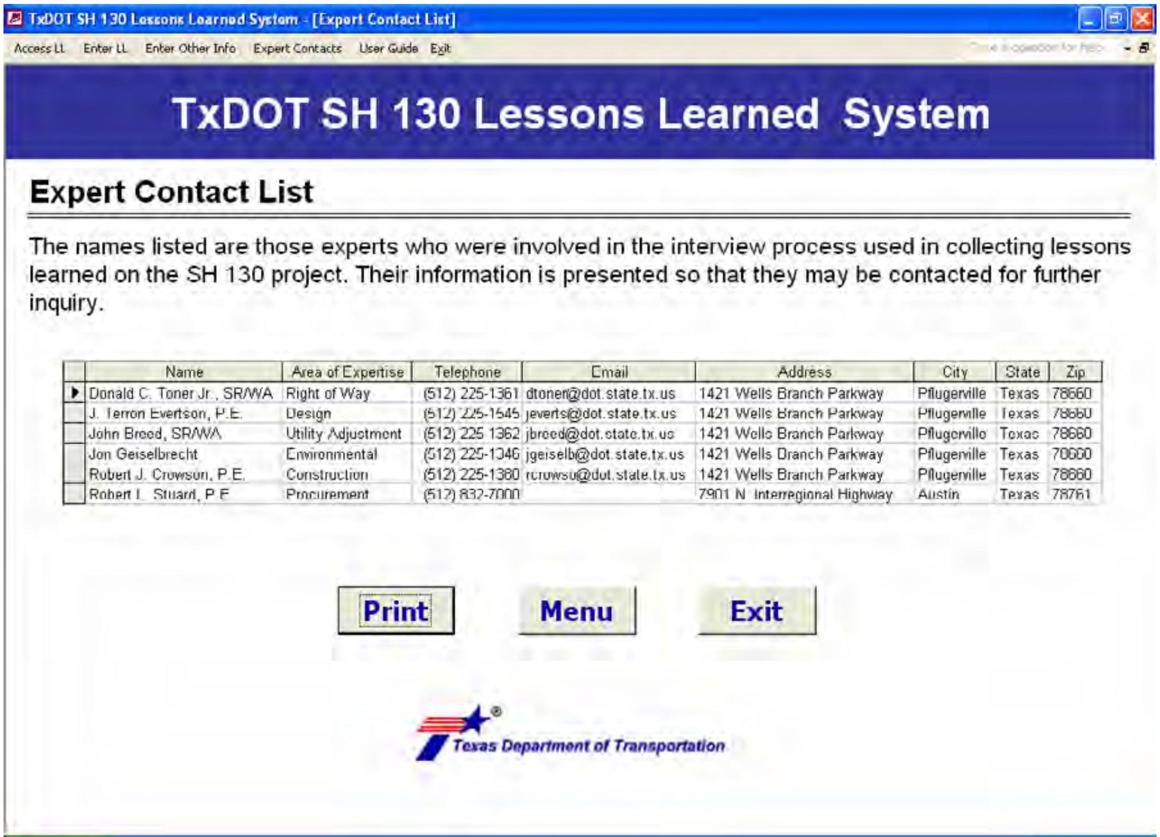


Figure B.7: Expert Contact List Form

Figure B.8 displays the Contact List report, which contains all of the pertinent information of the experts present in the system.

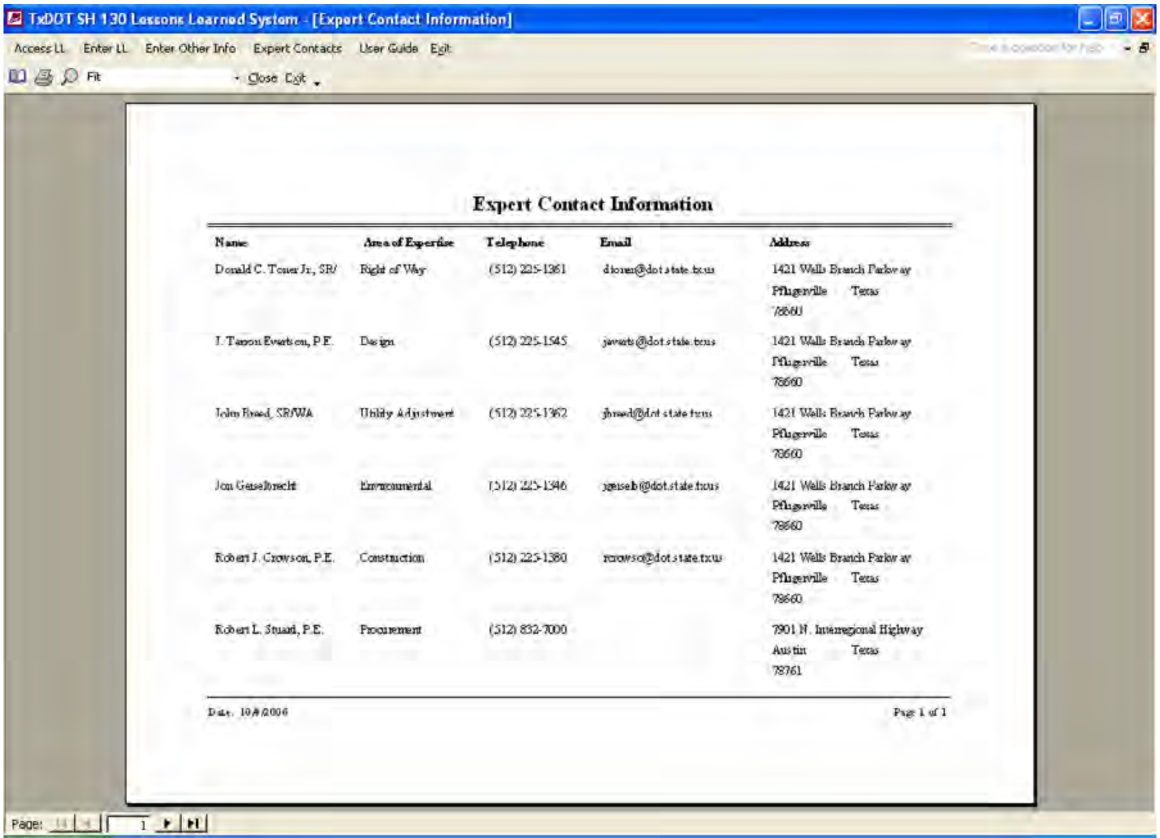


Figure B.8: Expert Contact List Report

B.6 Enter New Lessons Learned

By selecting the "Enter New Lessons Learned" option from the main menu, the user prompts a data entry form, Figure B.9. The user then fills in each of the fields that are associated with the new lesson learned, including "title," "context," "lesson learned," "impact," "source," "phase," "category," and "project." The phase, category, and project fields are designed as drop-down menus. Since this format provides menu choices for the searched items, users cannot use variant terms for these items. For example, if a user inputs a lesson that is related to right of way but chooses to abbreviate right of way (ROW) rather than spell it out, the system will not retrieve this lesson if "Right of Way" is chosen as the phase during a search. This feature ensures the integrity and effectiveness of the system's search features. However, this will create a problem if the lesson being entered does not relate to any of the phases or categories or projects on the drop-down lists. In such a case, the user can enter new information by means of the "Enter New Sorting/Support Data" feature described below. Once the user has finished entering and saving a lesson, he or she may choose to enter a new lesson, return to the main menu, or exit the system.

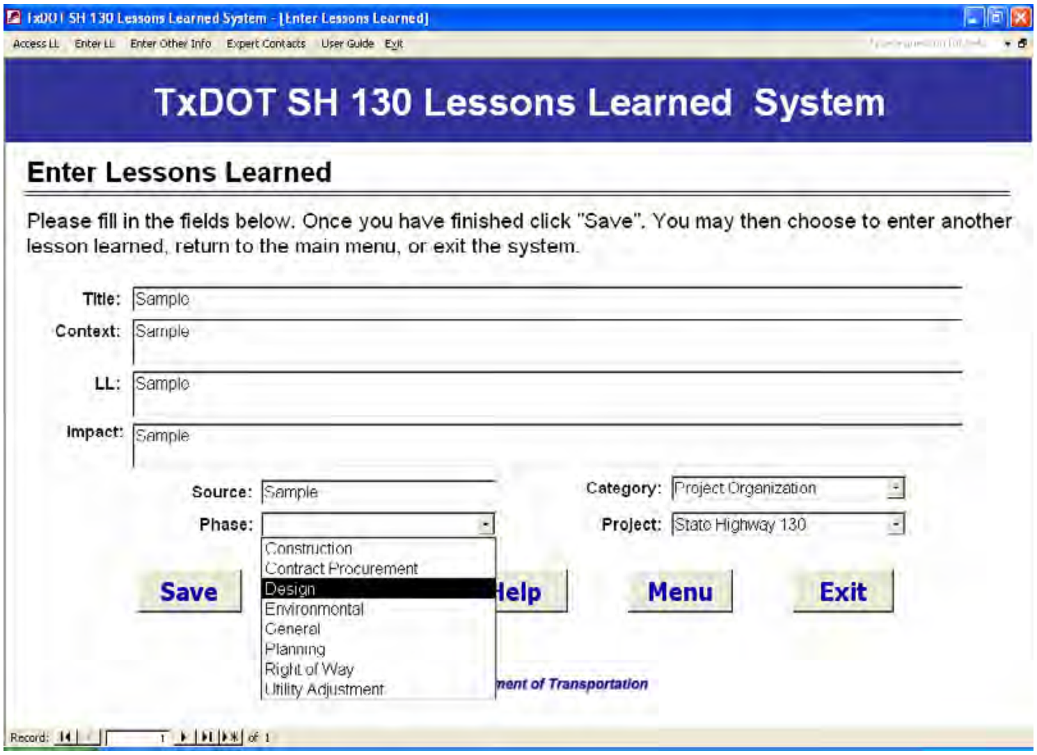


Figure B.9: Enter New Lessons Learned Form

B.7 Enter New Sorting/Support Data

The "Enter New Information" form, illustrated in Figure B.10, allows the user to enter new phases, categories, projects and contact information. The options to enter new phases, categories, and projects are designed to allow users to enter information that is related to a new lesson learned but that is not already stored within the database. For example, if a user wishes to enter a lesson related to a project other than State Highway 130, he or she must first enter the project name through the "Enter New Projects" option. Doing this, the new project is added to the drop-down list on the page when they go to enter the new lesson. Entering new phases, categories, and projects also updates the search drop-down menus so that they include these new elements when sorting lessons. The "Enter New Contact Information" option allows users to enter information of any new experts which they feel should be incorporated into the system.

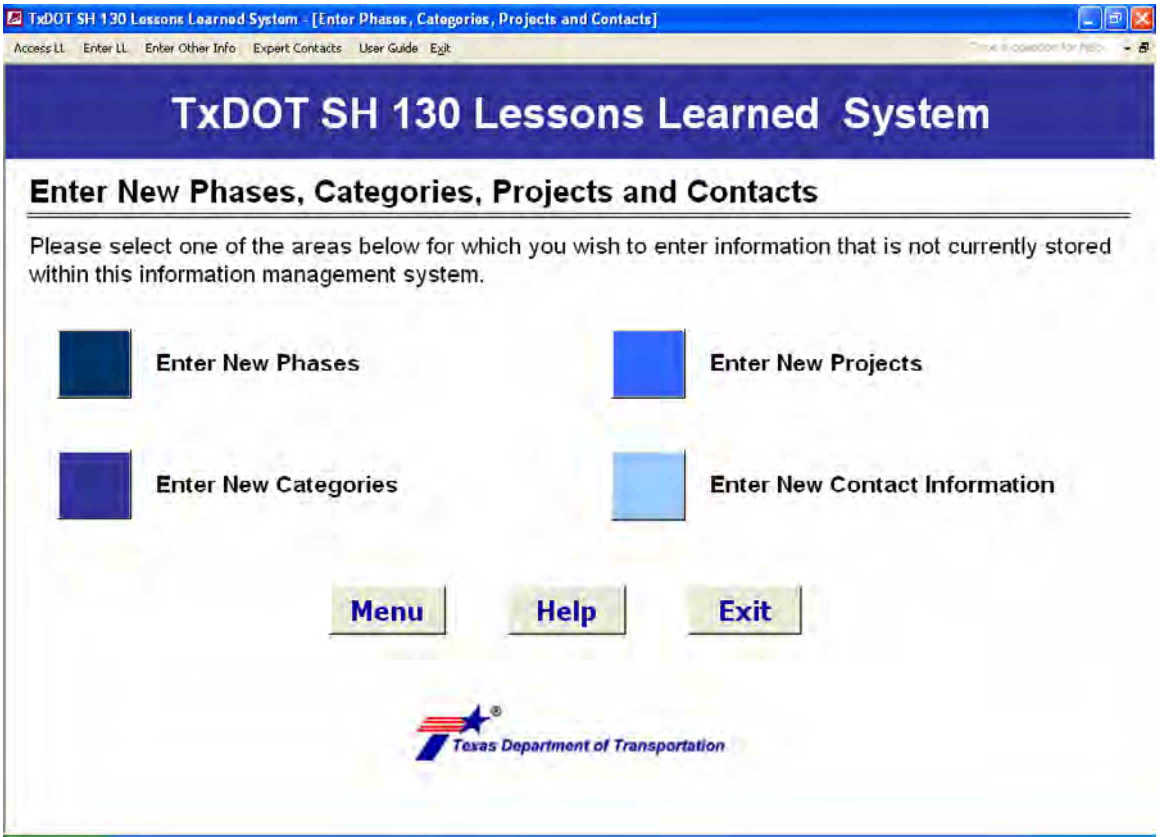


Figure B.10: Enter New Phases, Categories, Projects and Contacts Form

Once the user chooses the desired option, he or she is immediately taken to a data entry page. Figure B.11 displays the data entry form for entering new projects. The user is prompted to simply enter the new project name and to click "Save." Once they have done this they may choose to enter the name of another project, return to the main menu, or exit the system. The other three data entry forms are all similar to the one below.

Figure B.11: Enter New Projects Form

B.8 User Summary

Within the system there is a user summary labeled "User Guide." This feature presents the user with a general description of the system and provides guidelines for navigating the database. Figure B.12 shows the first page of the user guide. Additional pages that go into more detail on the system's features follow. Users are also presented with the option of printing a copy of the user guide, entering the main menu, or exiting the system.

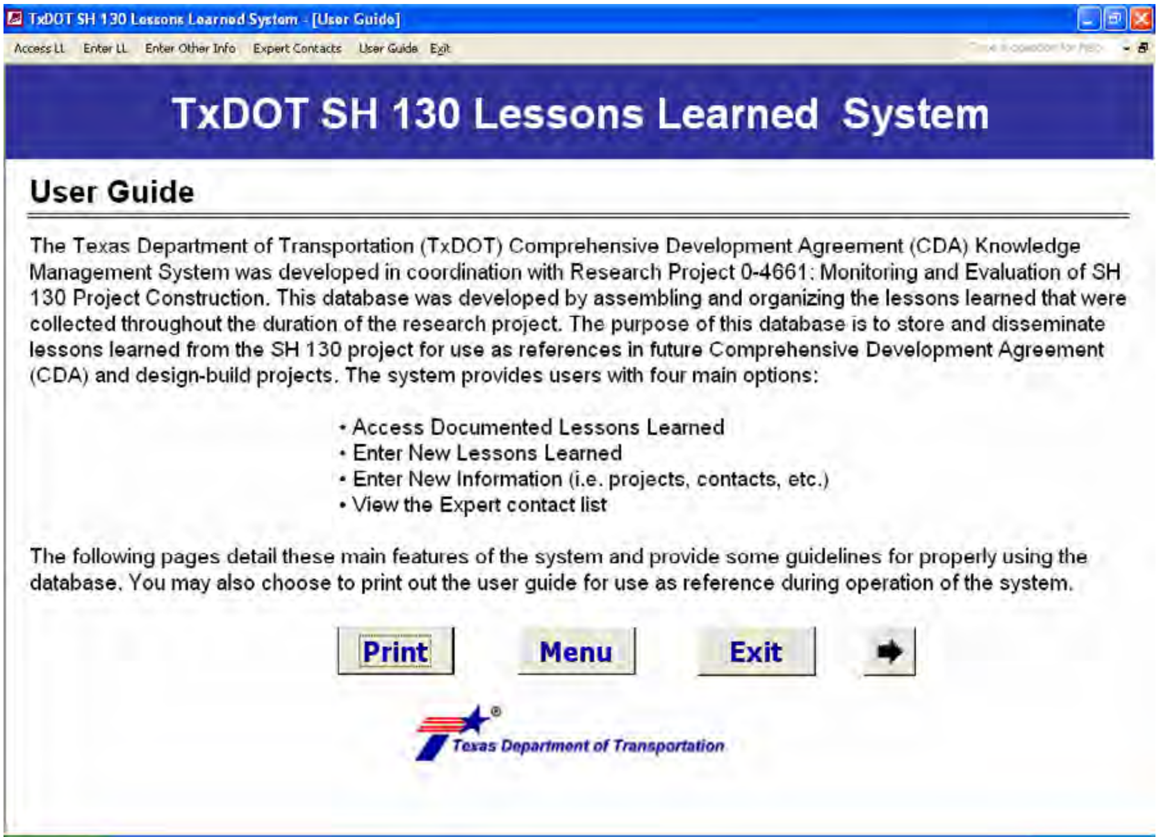


Figure B.12: User Guide Form

In addition to the general "User Guide," there are "Help" features included throughout the system. Most of the forms have "Help" buttons, which the user can click at any time. These buttons are linked to pop-up forms, which detail ways to use properly the feature at hand. These forms provide immediate assistance to the user if he or she is unsure of how to continue. Figure B.13 displays a typical help pop-up form.

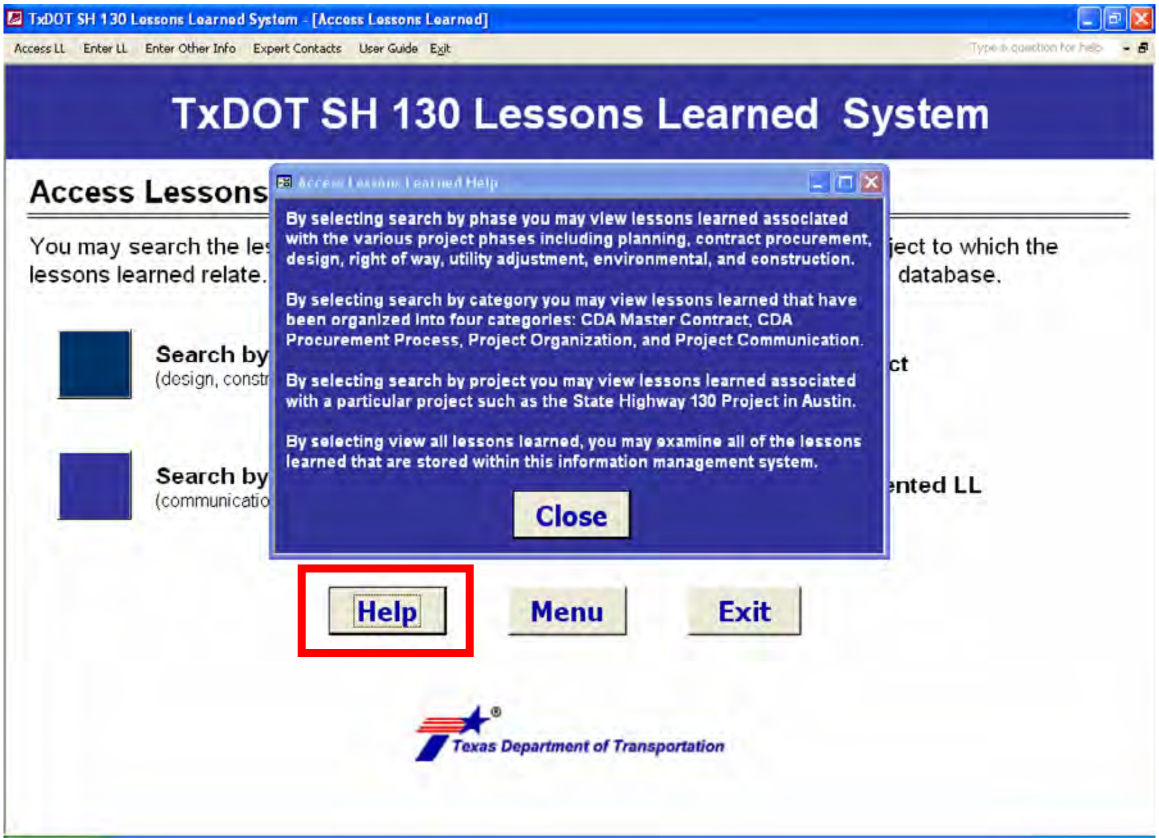


Figure B.13: Help Pop-up Form