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ISBN 978-0-309-43364-8 | DOI 10.17226/22413

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SUGGESTED CITATION

National Academies of Sciences, Engineering, and Medicine 2014. *Project Management Strategies for Complex Projects: Case Study Report*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/22413>.

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SHRP 2 Renewal Project R10

Project Management Strategies for Complex Projects Case Study Report



TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

SHRP 2 Renewal Project R10

Project Management Strategies for Complex Projects

Case Study Report

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Washington, D.C.

2014

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ACKNOWLEDGMENT

This work was sponsored by the Federal Highway Administration in cooperation with the American Association of State Highway and Transportation Officials. It was conducted in the second Strategic Highway Research Program, which is administered by the Transportation Research Board of the National Academies.

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Doyle Drive

Detroit River International Crossing

Richmond, Virginia, I-95 James River Bridge

Washington, D.C., and Baltimore, Maryland, InterCounty Connector

Executive Summary

Successful management of complex transportation projects requires a fundamental change in how projects are planned, developed, designed, procured, and constructed. The Strategic Highway Research Program 2 (SHRP 2) Renewal Research Project R10, Project Management Strategies for Complex Projects, is investigating strategies, tools, techniques, and methods that can be effectively used for complex-project management. The following report for Project R10 describes the results of Task 4 (Develop Case Studies) and a portion of Task 5 (Analyze Case Studies).

Fifteen projects in the United States and three international projects were investigated through in-depth case studies to identify tools that aid project managers of complex projects to successfully deliver projects. These 18 projects represent a number of different project types, locations, project sizes, and phases of project development. The tools identified from these projects fall into two areas: project development and project execution.

CHAPTER 1

Introduction

The definition of successful transportation project management is expanding to include broad, holistic, and long-lived measures of project performance (1). Marshall and Rousey (2) posit a three-part definition of successful project management as follows:

- “The scope, schedule and budget are in balance...
- Quality meets established standards and public expectations.
- No unresolved project issues, for example unresolved construction claims” remain.

As part of the redefinition of project success, the roles and responsibilities of project managers are expanding beyond the traditional cost-budget-quality triangle (3) to include management of relational, cultural, and stakeholder issues (4). In the midst of this evolution, the definition of project management has become blurred, and there is a lack of consensus on effective practices. For instance, one book describes project management as “the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements” (5). Other contemporary project management concepts focus on the identification and management of risk (6), while other concepts emphasize sustainability (7) and life-cycle conceptual estimating skills (8), among other issues.

The weight of evidence suggests a broad recognition that the nature of project management is changing but little agreement over how it is changing. In response to this situation, a research team at the University of Manchester developed an excellent conceptual framework and synthesizing field study of the changing nature of project management in 2003, titled Rethinking Project Management (9). The researchers applied a rigorous approach to this

problem and developed a framework for five new directions of thought to define the difference between routine project management and the management of complex projects in the 21st century. Figure 1.1 illustrates the framework. The five new directions evolve from robust logic and have important applicability to the SHRP 2 R10 Renewal research project.

Theory ABOUT Practice

Dir 1 Life-cycle Theory *OF* Projects & PM

  Project

From: the life-cycle model as “the” single theory of projects (e.g., “all projects comprise a series of defined tasks organized in a lifecycle of stages”), which is often portrayed as the actual reality of projects and the (often unexamined) assumption that the life-cycle model *is* (assumed to be) the actual “terrain” (i.e., the actual reality “out there” in the world).

Toward: multiple theories which seek to understand the complexity of projects: e.g., the social process and the flux of events, social interaction, stakeholder relations, and individual human action and new models and theories which are explicitly presented as only *partial* theories of the complex “terrain.”

Theory FOR Practice

Dir 2 Projects as Instrumental Processes

  Project

From: the instrumental life-cycle image of projects as a linear sequence of tasks to be performed on an objective entity “out there,” using codified knowledge,

procedures, and techniques and based on an image of projects as temporary apolitical production processes.

Toward: concepts and images which focus on social interaction among people, illuminating the flux of events and human action and the framing of projects (and the profession) within an array of social agenda, practices, stakeholder relations, politics, and power.

Dir 3 Product Creation Value Creation

From: a focus on product creation—the development or improvement of a physical product, system or facility, etc.—and monitored and controlled against specification (quality), cost, and time.

Toward: a focus on value creation as the primary focus of projects, programs, and portfolios. “Value” as having multiple meanings linked to different purposes: organizational and individual.

Dir 4 Narrow Conceptualization

Broad Conceptual

From: the narrow conceptualization of projects as temporary production systems, starting from an objective or goal “given” at the start, and named and framed around single disciplines, e.g., IT projects.

Toward: the broader conceptualization of projects and programs as being multidisciplinary, having multiple purposes, not predefined, but permeable, contested, and open to renegotiation throughout.

Theory IN Practice

Dir 5 Trained Technicians □ □Reflective Practitioners

From: trained technicians who follow detailed procedures and prescriptive techniques based on mainstream project management theory (re: the “from” parts of Dir 1–4).

Toward: reflective practitioners who can operate effectively in complex project environments through experience, intuition, and the pragmatic application of theory.

Figure 1.1. The five new directions of thought in rethinking project management

[after Winter and Smith (9)].

Direction 1 portrays the shift from a “life-cycle theory of projects and project management” to a “complexity theory.” Essentially, this change entails recognizing that projects are influenced by more external agents than just technical engineering and construction means and methods. The authors advocate developing multiple theories to account for multiple external influences, in contrast to current methods that treat external influences as risks. Following directly from the move to complexity theory, Direction 2 emphasizes a change from conceptualizing projects as a series of static, linear, and discrete events toward recognition of the interactive, interpersonal, and dynamic nature of modern projects. In the same vein, the report also points out the need to refocus on “value creation” rather than on “project creation,” a shift that constitutes Direction 3. Again, this is a paradigm shift to treat projects as end states that have a purpose in society rather than as an assembly of well-engineered and manufactured parts. Direction 4 suggests a trend toward integrated multidisciplinary structures with hybrid forms of governance. Finally, the Winter and Smith (9) report seeks to shift the practice from training

project managers to use various analytical tools to inspiring project managers to be thoughtful, resourceful, and pragmatic in the application of their education and experience to managing complex projects. It is this direction of thought—Direction 5—that best underscores the ultimate objective of the SHRP 2 R10 Renewal research project.

Traditional project management involves integrating the three dimensions of a project that must be satisfied to deliver the required scope of work (2). These are the technical, schedule, and cost dimensions. The traditional approach to project management has generally served the industry well during the expansion of the U.S. transportation infrastructure. However, this infrastructure is now getting old; much of the highway system has exceeded its original design life and is no longer functioning at the capacity for which it was designed (10). This situation has created an extremely urgent need to address the aging infrastructure problem (11, 10). As a result, a shift from building new infrastructure to replacing, expanding, or renewing existing infrastructure has occurred. The project management issues involved with infrastructure renewal are markedly different from the issues for new construction, a fact that furthers the need for a change in project management approaches to the nation's infrastructure.

Project managers of complex projects, both large and small, must ultimately optimize the available resources (time and money) and integrate them with the technical performance needs of the project (design) while operating under both known and unknown constraints (context). At the same time, managers must accommodate the requirements of new financing partners and funding models (financing). As a result, complex-project management involves an increase in the project manager's skill set from the traditional three dimensions to encompass five dimensions, as shown in Figure 1.2. Generally speaking, this requires the owner to think continually about risk in areas that include budgeting, schedule, designing, allocating, and pricing.

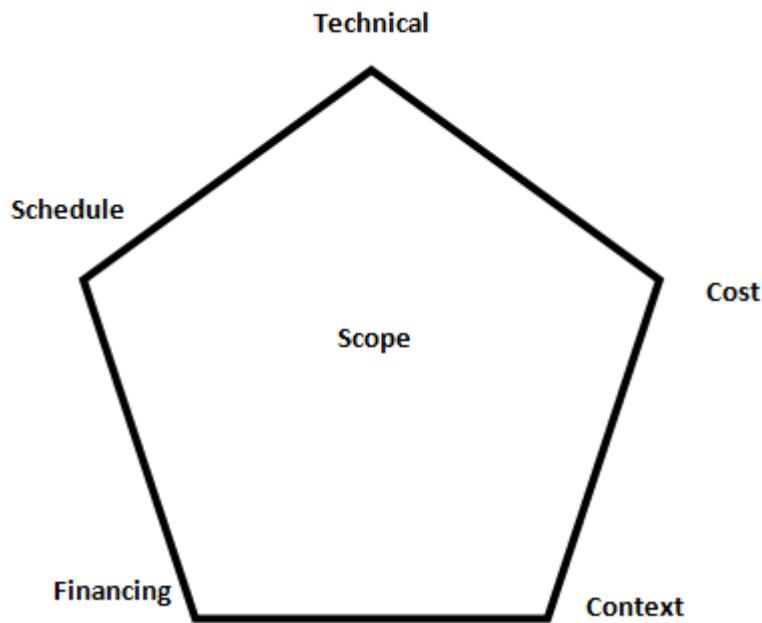


Figure 1.2. Complex-project management.

Complex-project management tools must reach beyond merely adding arbitrary risk contingencies in budgets or risk-shedding clauses in contracts. These tools must furnish agencies with the ability to quantify the potential impact of risk as well as assist them in determining the most appropriate means to allocate risk among themselves and the industry parties. Building on the foundation laid by the UK initiative on new directions in project management, current project management knowledge can be organized in a supplementary framework that is grouped into the three traditional project management knowledge areas (cost, schedule, and technical) and combined with two additional factors that are often present in complex projects: project context and project financing. In keeping with Direction 1 toward using theories of complexity to model project management, the emerging model recognizes that the traditional project management approaches to cost, schedule, and design will be more challenging because they must now be viewed as part of a social, dynamic, and broadly conceptualized process. Adding an expanded,

more-complex understanding of cost, schedule, and design to the new project management factors of context and financing creates a framework organized around five critical dimensions of complex-project management. Thus, complex projects can be differentiated by the requirement to actively manage in more than the three dimensions of traditional project management.

Although very broad and conceptual in nature, the five new directions of thought for restructuring project management were extremely helpful for developing an applied model of complex-project management. Direction 1 suggests the need to account for external project factors instead of perceiving them as risks. Direction 2 argues that project managers must view projects as interactive processes rather than as linear functions. This change clearly affects cost, schedule, and technical issues and requires that project managers of complex projects continually update schedules, costs and budgets, and design as interactive, interdependent processes. Direction 3 has implications for how managers of complex projects consider scheduling decisions, which include project delivery, procurement, integrated supply chains, use of prefabrication, and so forth. Direction 4 encourages project managers to think of the project from multiple viewpoints with multiple purposes and with no set predefined project parameters. Finally, Direction 5 encourages project managers to rely on experience and intuition instead of detailed procedures. A number of factor categories affect each of the identified five dimensions. The lists of categories within each dimension are for descriptive purposes only and are not exhaustive.

- Complexity Dimension 1: Cost. This dimension involves quantifying the scope of work in dollar terms. The cost dimension includes categories such as
 - Risk,

- Preliminary program,
 - Planning and construction, and
 - Issues.
- Complexity Dimension 2: Schedule. This dimension relates to the calendar-driven aspects of the project. The schedule dimension comprises categories such as
 - Time,
 - Risk,
 - Planning and construction,
 - Technology, and
 - Mathematical modeling.
- Complexity Dimension 3: Technical. This dimension includes all of the typical engineering requirements. The technical dimension comprises categories such as
 - Scope.
 - Internal structure,
 - Contract,
 - Design,
 - Construction, and
 - Technology.
- Complexity Dimension 4: Context. This dimension encompasses the external influences affecting project development and progress. The context dimension comprises categories such as
 - Stakeholders.
 - Project-specific requirements,

- Local issues,
 - Resource availability,
 - Environmental issues,
 - Legal and legislative issues,
 - Global and national conditions, and
 - Unusual conditions.
- Complexity Dimension 5: Financing. This dimension relates to the need for understanding how the project is being paid for. The financing dimension comprises categories such as
 - Process.
 - Public involvement,
 - Revenue stream,
 - Asset value,
 - Project delivery methods, and
 - Risk.

To explore each of these dimensions in greater depth and discover implementation tools for managing the sources of complexity arising from these dimensions, a number of case studies of projects in the United States and around the world were developed and analyzed.

CHAPTER 2

Conducting Case Studies

Case studies can be used to look in depth at a project to focus on attitudes, behaviors, meanings, and experiences by obtaining information from a number of different sources related to the project. For the SHRP 2 R10 Renewal research project, a series of in-depth case studies were conducted to build on the literature review that identified the five dimensions of project management and the factor categories to find tools to use in managing complex projects as well as to supplement the knowledge framework previously created.

Case study research in construction has encountered much criticism of aspects such as small sample size and unwarranted generalization of results, lack of trust of participants, and rigor of protocol. To address these criticisms, the research team used a variety of methods that included using different sources of information, maintaining a chain of evidence, and searching for patterns among the data through data coding. Fundamental observations were initially sought, but often key variables emerged during data collection and analysis. Thus, the final plan included flexibility to change form and format as unexpected findings developed, which allowed the researchers to exploit those opportunities. Through the analysis and conclusions of the report, explanations were formed to tie conclusions with assembled data to validate the research and its findings (12, 13).

The analysis was conducted on the following three levels:

- *Level 1.* Select complex projects of different sizes, in different countries, with different reasons for complexity, and at different levels of success, as identified in the literature review and discussions with people with industry knowledge.

- *Level 2.* Obtain published reports of complex case study projects from the highway, airport, and transit sectors.
- *Level 3.* Interview public transportation agency personnel, contractors, and consultants with experience in complex-project management.

2.1 Level 1

The choice of projects to further investigate as in-depth case studies was determined through the literature review and agency surveys, as well as through discussions with the R10 panel and transportation industry leaders. An initial list of possible case study projects was created from the Federal Highway Administration (FHWA) major projects website as well as from communications with industry leaders. This list was originally composed of approximately 95 projects in the United States and a dozen projects internationally.

The research team then interviewed Carl Gottschall, the FHWA major projects team leader. The purpose of this interview discussion was to reduce the number of possible projects. The research team described the purpose of the research and the five dimensions, and on the basis of Mr. Gottschall's knowledge of the projects, the list of possible projects in the United States was reduced to approximately 20. Following this discussion, the team evaluated the size, type, level of success, location, and current project phase of each of the projects. The team determined that a variety in each of these areas was desirable. The team also presented the possible projects to the SHRP 2 Renewal Panel for their input. On the basis of this information, the team identified 15 projects in the United States to use as case studies. Later, during the process of setting up the interviews, one of the originally identified projects withdrew from consideration and was replaced by another project. The projects identified are geographically

dispersed, as shown in Figure 2.1, and represent different types of agencies in different climates and conditions. Similar discussions were held to identify the international case study projects.



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Figure 2.1. Location of case study projects in the United States.

In addition to being geographically dispersed, the projects also represent a number of different types of projects, as shown in Table 2.1. The case study projects are also in different phases of development. Some projects, such as the Detroit River Bridge, are still in planning. Other projects were completed, such as the Lewis and Clark Bridge, while others are somewhere in between, such as Doyle Drive.

Table 2.1. Case Study Project Type

	Corridor	Bridge	Bridge and Corridor	Tunnel and Bridge or Roadway	Transit
Number of cases	7	4	3	2	2

2.2 Level 2

The second level of analysis was to obtain documents and reports on each of the identified case study projects. These documents were obtained before, during, and after the interviews. These documents served several purposes. An important reason for these documents was to prepare for the interview and obtain a base understanding of the project. These documents also helped to identify tools and indicated the actual implementation of the tools. Some of the documents are tools in themselves.

2.3 Level 3

The primary input to the case studies was gathered through the Level 3 analysis of structured interviews with agency personnel, contractors, and consultants that have been part of teams involved with the identified projects. The structured interview outlines were developed similar to the method prescribed by the U.S. Government Accountability Office (GAO) (14). The GAO method states that structured interviews can be used when “information must be obtained from program participants or members of a comparison group ... or when essentially the same information must be obtained from numerous people for a multiple case-study evaluation” (14).

Both of these conditions applied to this project. Therefore, the tool is appropriate for the research.

The process involves developing a questionnaire that is made available to each interviewee before the interview and then collecting responses in the same order by using the same questions for each interviewee. The final questionnaire is shown in Appendix A. The information can be gathered by both face-to-face and telephone interviews. Time is given per the GAO method to ensure that the interviewee understands each question and that the data collector understands the answer. In addition, interviewees were allowed to digress as desired, which allows the researchers to collect potentially valuable information that was not originally contemplated. The output is used to present the agencies' perspective on various points analyzed in the subsequent tasks.

In addition to gathering data about the issues and tools on the project through the personal interviews, key project personnel were asked to rate the complexity on each of the five dimensions. The responses will be indexed to create a complexity map for each project. A sample complexity map is shown in Figure 2.2 for a hypothetical project, with an extremely complicated schedule, cost structure, and technical design and moderate financing and context complexity.

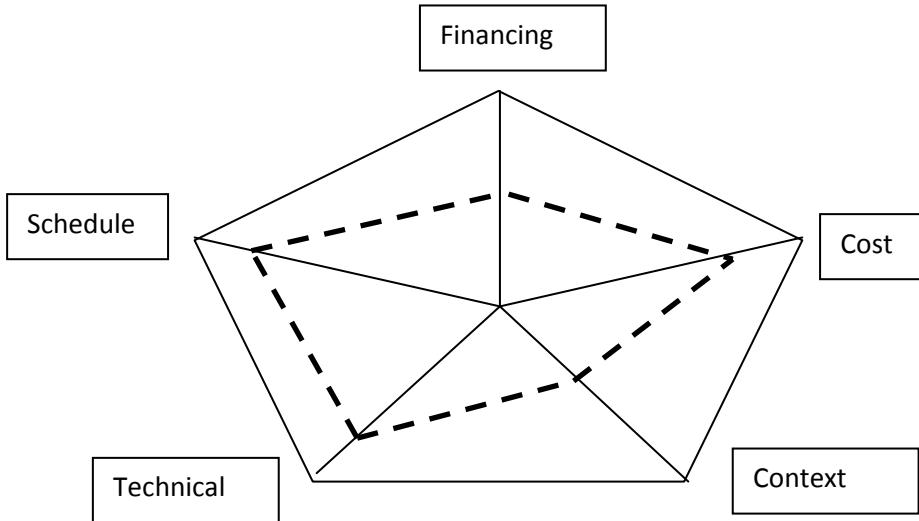


Figure 2.2. Sample project complexity map.

Once the questionnaire was developed and pilot tested, the team held a telephone-based training session. Each member of the team was to conduct at least one case study interview. One way to ensure consistency in the data collection was through developing the questionnaire, and another was to hold the training. This training was a 2-hour presentation of the questionnaire, a demonstration of the interview technique, and discussion of the documentation for reporting on the project. Throughout the meeting, team members were encouraged to ask questions and have a discussion.

On completion of the interviews, the interviewee collected any new documentation from the interview and submitted three documents for completion of the interview. The first document consisted of typed notes on the interview questionnaire. The second document presented the same information in a condensed, different format. The final document was a summary of the project and information about the most important issues and tools on the project. Once all of this information was submitted, the case study was considered complete.

CHAPTER 3

Case Study Executive Summaries

3.1 Capital Beltway Project

3.1.1 Information

The Capital Beltway project in northern Virginia is a complex project currently in the construction phase. It consists of four high-occupancy vehicle (HOV)/high-occupancy toll (HOT) lanes of 14 miles, lane connections, construction or reconstruction of 11 interchanges, and replacement of or improvements to more than 50 bridges. The total awarded value of the project for construction and administration is \$1.4 billion. When financing and design are included, the total awarded value of the project reaches \$2.2–2.4 billion. Planning of the project began in 2003. One interesting fact about this project is that it resulted from an unsolicited proposal issued in 2004 and is an owner-negotiated public–private partnership (PPP). Actual construction began in July 2008, and the project is scheduled to be completed in 2013. Tolling and revenues are expected to start on December 21, 2012.

3.1.2 Complexity

The Capital Beltway HOV/HOT Lanes Project was delivered by PPP with the design-build (DB) approach. Although the Virginia Department of Transportation (DOT) megaproject team had previous experience with DB, there was still some unfamiliarity that made the project delivery method more complex than a typical project. Developing the HOT network and switchable hardware to accommodate HOT and HOV users was a very challenging task for intelligent transportation systems (ITS). There are many technical factors to consider for developing

HOT/HOV lanes such as choosing a pass type (electronic pass or not, or both), determining how to recognize the number of people in the vehicles and how to distinguish animals or “dummy” passengers from human passengers, and many other technical issues. In addition, it was necessary to make sure that the developed system was not unlawful. For example, the legal issues involving use of photos for toll enforcement needed to be investigated before application. Different sources of funding and atypical financing processes related to the PPP were challenging. The radar complexity diagram presented below displays the dimensional complexity scores provided by the interviewees (see Figure 3.1).

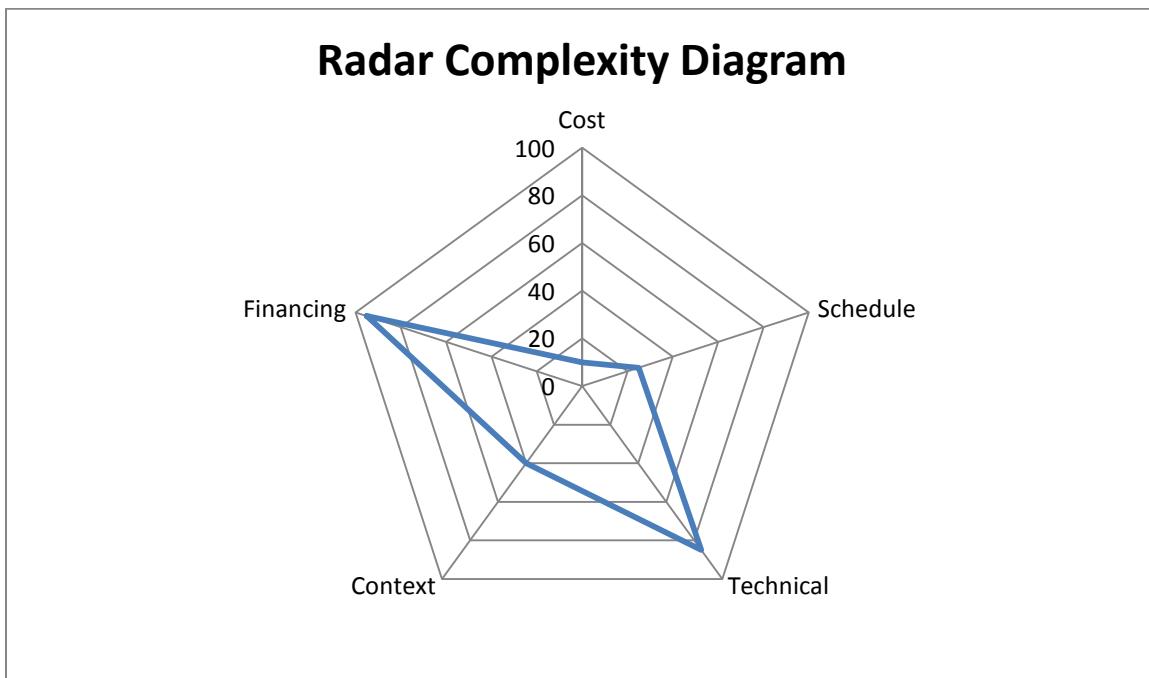


Figure 3.1. Capital Beltway complexity map.

3.1.3 Primary Tools

The primary tools used for the project included preparing a finance plan and early cost model, assembling an owner-driven project team, and establishing a public involvement plan.

3.2 Detroit River International Crossing Project

3.2.1 Information

The purpose of the project is to provide a new Detroit River Crossing connecting Detroit, Michigan, with Windsor, Canada. This bridge would complement an existing 81-year-old toll bridge that is privately owned (Ambassador Bridge) and an existing 80-year-old tunnel (Detroit–Windsor Tunnel) that has limitations to usage by commercial vehicles. The project will also provide freeway-to-freeway connection between I-75 in Detroit and Hwy 401 in Windsor. The overall project has 10 primary components and various funding sources associated with each component. The need for the project is to provide redundancy for mobility and trade between the countries, support economies by connecting the major freeways, and support civil, national defense, and homeland security emergency needs.

3.2.2 Complexity

Multiple agencies are involved in the project (the Michigan DOT and FHWA in the United States and Ontario Province and Transport Canada in Canada), and as a result, separate documents are required for each country. Thus, multiple stakeholders showed interests and involvement in each country. Project funding is from multiple sources including tolling. Political issues also make this project complex (see Figure 3.2). Those issues include need for legislation authorizing PPP for the project, pressure related to the competing interests associated with the privately owned Ambassador Bridge, and national attention to the project to support streamlining the delivery. The projected financial cost for the project is more than \$1.8 billion.

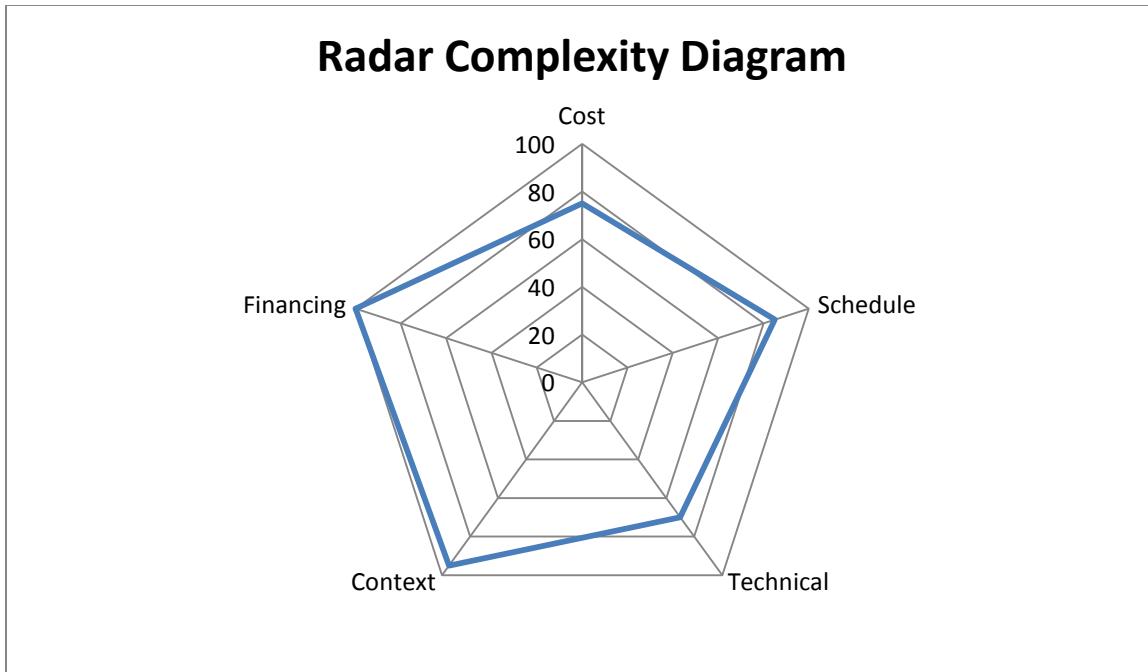


Figure 3.2. Detroit River International Crossing complexity map.

3.2.3 Primary Tools

The primary tools used for the project include selecting a contracting method based on project outcomes and establishing a public involvement plan.

3.3 Doyle Drive Project

3.3.1 Information

The Doyle Drive project, also known as Presidio Parkway, is a unique project that is one gateway to the Golden Gate Bridge in San Francisco, California. The Doyle Drive corridor, 1.5 miles in length, was originally built in 1936 to usher traffic through the Presidio military base to connect San Francisco and the Golden Gate Bridge. Doyle Drive is located in a high seismic hazard zone, and the original structure was not built to withstand projected earthquakes. Seismic retrofit was completed in 1995, which was intended to last for 10 years. The project is actually

eight different contracts that will result in a new roadway, new structures that include bridges and tunnels, and a depressed roadway section.

3.3.2 Complexity

Contributing to the complexity of this project is the number of different finance sources being used for this project (see Figure 3.3). In addition, one of the contracts still in the planning phase is expected to be PPP.

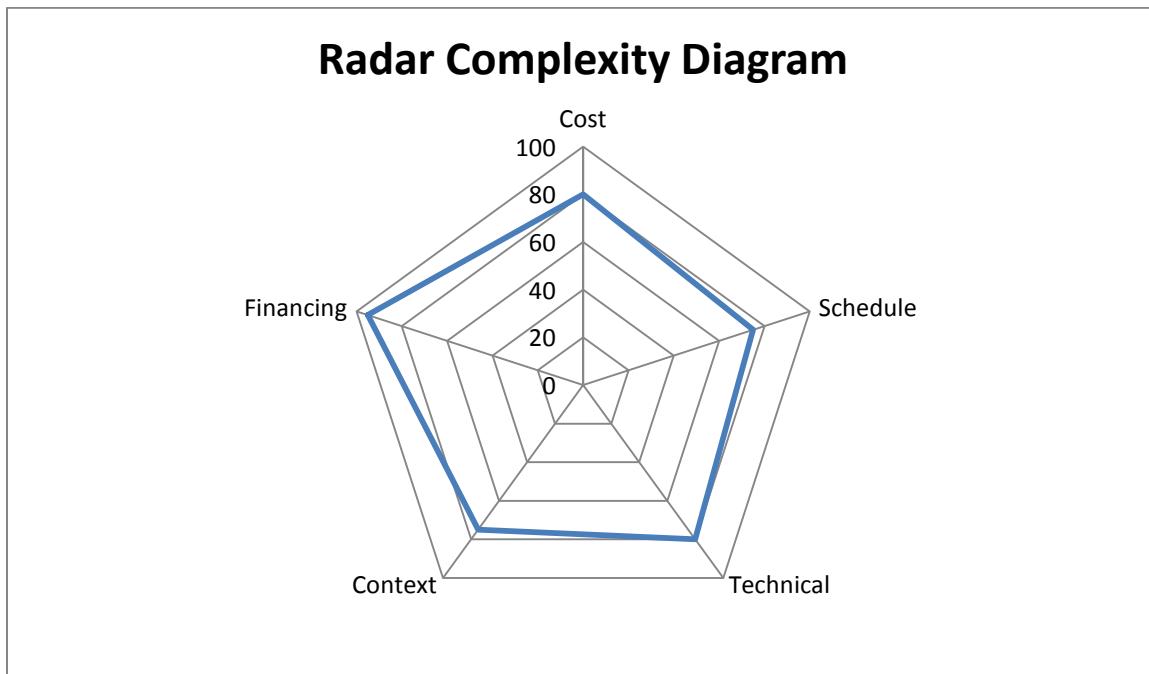


Figure 3.3. Doyle Drive complexity map.

3.3.3 Primary Tools

The primary tools for this project include multiple contracts, various project delivery methods, incentives to accelerate project delivery, value engineering, contractor-initiated changes and suggestions, and extensive and thorough monthly progress reports.

3.4 Green Street Project

3.4.1 Information

The project consisted of recycling of asphalt and portland cement concrete rubble into high value added materials and focused on development of high value substructure aggregates that are structurally superior to conventional aggregates. The scope also included mechanistic-based structural asset management and design protocols. The project also executed several field-test sections to provide field validation of the structural designs.

3.4.2 Complexity

Use of recycled rubble as structural material is unproven and does not fit conventional road-building practice. Therefore, the project used design-supply-build principles that incorporated mechanistic design and field validation of the system developed. Figure 3.4 illustrates the complexity of this project.

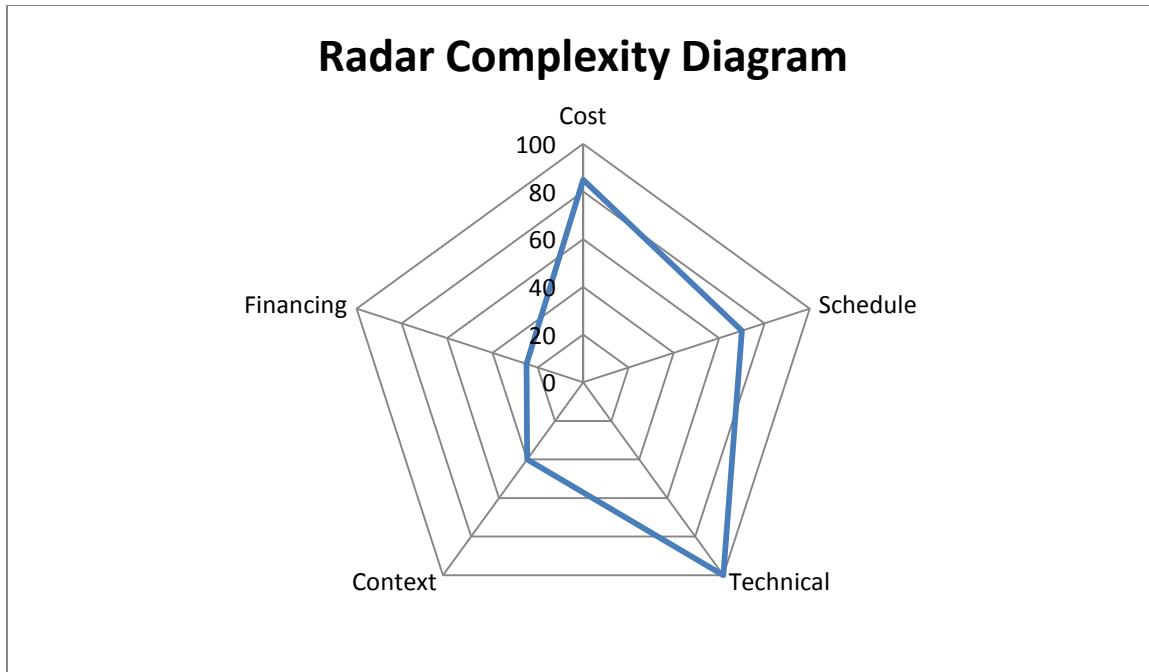


Figure 3.4. Green Street complexity map.

3.4.3 Primary Tools

The primary tools used for the project include the establishment of flexible design criteria and the selection of a contracting method that is based on project outcomes.

3.5 Heathrow T5 Project

3.5.1 Information

The Heathrow Airport T5 project includes constructing a new terminal building, a new air traffic control tower, ground traffic infrastructures (such as rail, underground, road, and guideways), and other auxiliary facilities (i.e., water tunnels). The planning phase of the project can be dated back to 1986, and the first phase of the project was completed in 2008. A second satellite building is still under construction and expected to be delivered by 2011.

3.5.2 Complexity

This project is one of the largest projects in Britain's engineering history and the biggest construction site in Europe. The project can be traced back to 1986, when the proposal was approved. Since then, the planning and design phases of the T5 project have experienced turbulent changes (e.g., technology, economic conditions, ownership, user requirements), which have created significant management challenges for a project of this scale. Further, the total cost of the project is £4.3 billion, and numerous contractors, subcontractors, suppliers, subsuppliers, regulatory agencies, and other stakeholders are involved. The project is financed from a variety of revenue sources despite its huge uncertainties. Figure 3.5 depicts the complexity of this project.

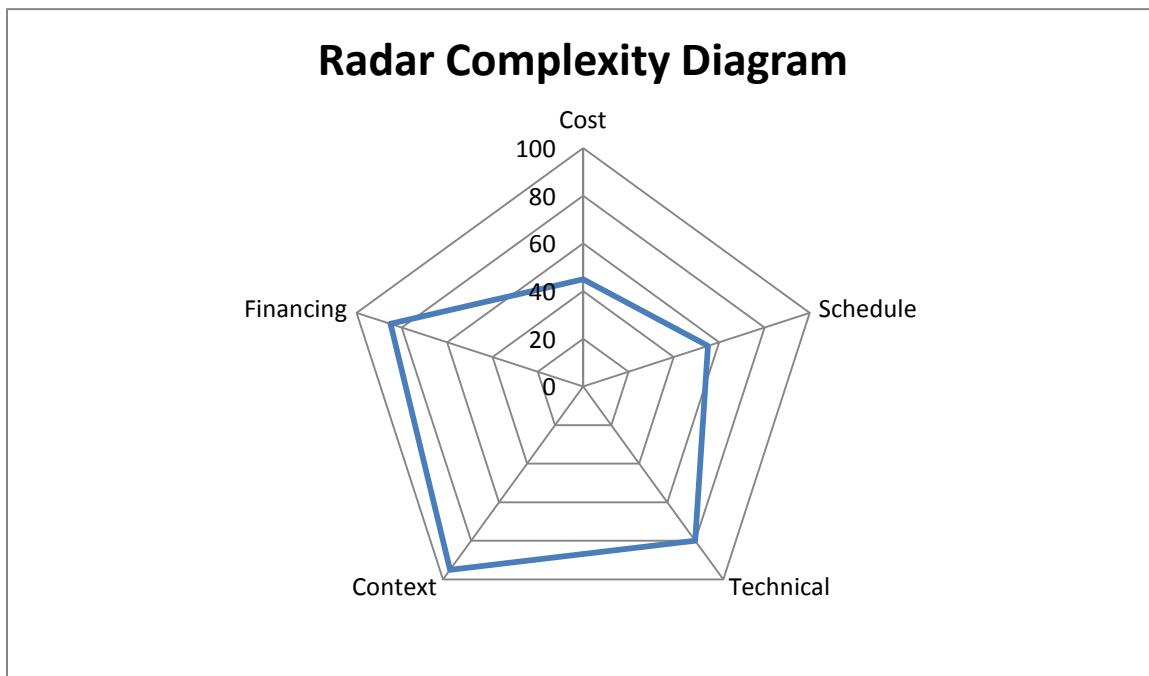


Figure 3.5. Heathrow T5 complexity map.

3.5.3 Primary Tools

The primary tools used for the project include performing a comprehensive risk analysis, assembling an owner-driven project team, and defining project success by each dimension as required.

3.6 Hudson-Bergen Light Rail Minimum Operable Segment

3.6.1 Information

The Hudson-Bergen Light Rail Transit System (HBLRTS) is a 20.3-mile-long light rail project that connects the densely populated New Jersey Hudson River waterfront communities. The project also supports significant economic development that continues to take place in the region. The HBLRTS was built in three minimum operable segments (MOS). MOS2 (the subject of this case study) is a 6.1-mile-long system extending from Hoboken to the Tonnelle Avenue Park-and-Ride facility in North Bergen, with an extension between 22nd Street and 34th Street in Bayonne. MOS2 features a major tunnel (the Weehawken tunnel with a length of 4,100 feet), which includes the new Bergerline station at a depth of 160 feet from the surface.

The HBLRTS started as a traditional design-bid-build project. In 1994, it was determined that by using the traditional approach, the first operating segment would not be in service until 2005 because of funding constraints and other considerations. Because of these concerns, NJ Transit decided to use the design-build-operate-maintain (DBOM) approach for project delivery. Using this approach, they were able to shave more than 3 years from the MOS1 duration. For MOS2, the NJ Transit decided to retain the services of the DBOM contractor of the first segment, the 21st Century Rail Corporation (a subsidiary of Washington Group International). So the MOS2 DBOM contract was negotiated as a large change order to MOS1.

3.6.2 Complexity

The HBLRTS is the first public transit project in the nation to use the DBOM construction methodology. To get enough funds to make the project feasible, Grant Anticipation Notes and several bonds were issued because the Full Funding Grant Agreement pays according to a multiyear schedule. Also, the project was constructed in populated and built-up areas, which was challenging. Moreover, the length of the project contributed to the complexity in that the number of municipalities that the project spanned was large compared to projects undertaken before.

Figure 3.6 shows the complexity of the HBLRTS.

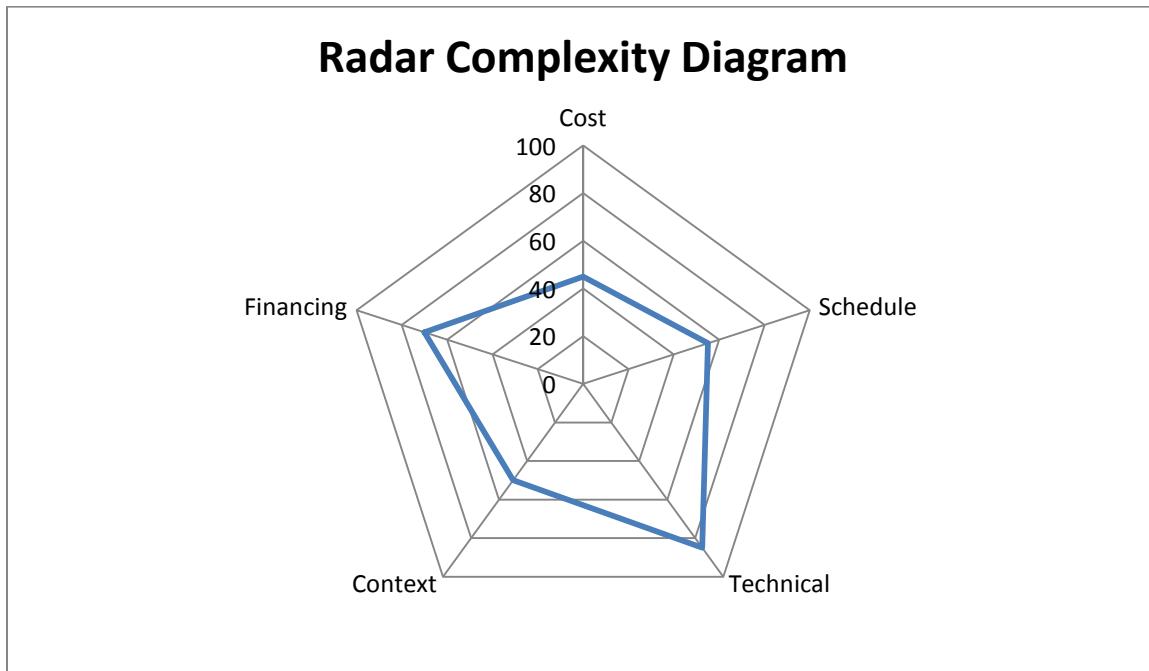


Figure 3.6. Hudson-Bergen Light Rail complexity map.

3.6.3 Primary Tools

The primary tools used for the project include selecting a contracting method based on project outcomes, defining a political action plan, determining the required level of involvement in right-of-way (ROW) and utilities, and establishing a public involvement plan.

3.7 I-40 Crosstown Project

3.7.1 Information

The I-40 Crosstown project relocates 4.5 miles of the I-40 Crosstown in Oklahoma City, Oklahoma, from approximately May Avenue to the I-35 interchange, which includes five major bridge structures. The project consists of 10 lanes designed to carry 173,000 vehicles per day at 70 mph.

This case study project includes

- 4.5 miles of new Interstate,
- ROW acquisition,
- Agreements with railroad, and
- 23 separate work packages in the construction phase.

3.7.2 Complexity

The project is complex because of the challenge of matching the capabilities of the local design and construction industry to the scale of the project. In addition, the availability of funding and the stakeholder impact, which includes relations with the railroad and ROW, added to the complexity of the project (see Figure 3.7).

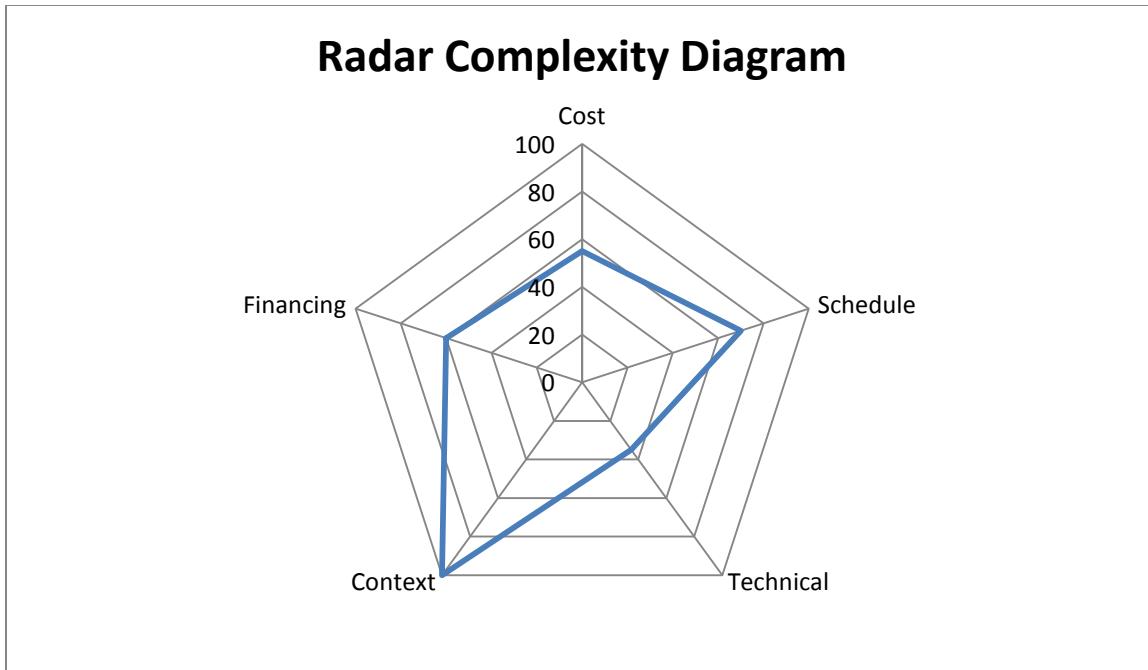


Figure 3.7. I-40 Crosstown complexity map.

3.7.3 Primary Tools

The primary tools used for the project include defining project success by each dimension as required, assembling an owner-driven project team, and establishing a public involvement plan.

3.8 I-95 New Haven Harbor Crossing Corridor Improvement Program

3.8.1 Information

The I-95 New Haven Harbor Crossing Corridor Improvement program comprises seven completed and three current projects. The total program is estimated to cost \$1.94 billion. This is a multimodal transportation improvement program that features public transit enhancement and roadway improvements along 7.2 miles of I-95 between Exit 46 to Exit 54.

The active projects include

- Replacing the existing bridge with a new signature structure, the Pearl Harbor Memorial Bridge (\$416 million),
- Main span foundations and northbound west approach (\$137 million), and
- Route 34 flyover (\$97 million).

3.8.2 Complexity

The Pearl Harbor Memorial Bridge is the first extradosed bridge in the nation and as such could add to the complexity of the project from a technical point of view. The magnitude of the project and its first-ever use in the United States caused the first bidding process to result in no bids. This required the owner to replan and repackage the project at great cost and delay. Furthermore, the project has multiple packages consisting of transit and highway work in a densely populated area spanning several municipalities. The construction work is conducted while the highway remains open to traffic (see Figure 3.8).

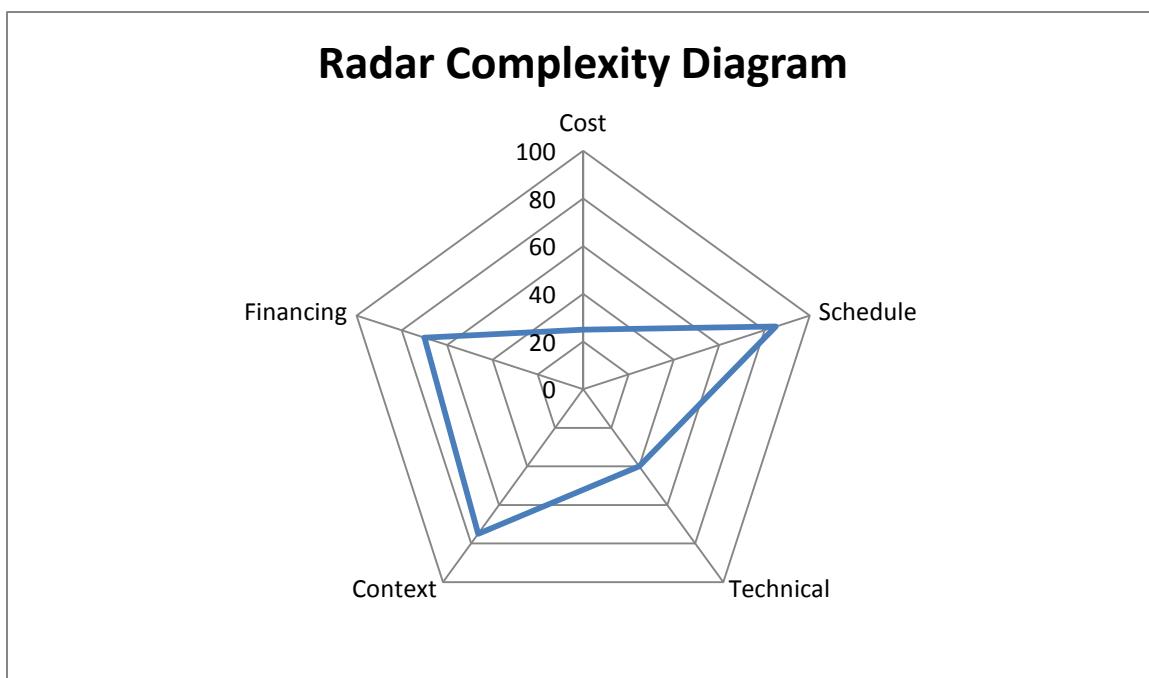


Figure 3.8. I-95 New Haven Harbor Crossing complexity map.

3.8.3 Primary Tools

The primary tools used for the project include performing a comprehensive risk analysis and determining the required level of involvement in ROW and utilities.

3.9 I-595 Corridor Roadway Improvements Project

3.9.1 Information

The I-595 Corridor Roadway Improvements project in Florida consists of the reconstruction of the I-595 mainline and all associated improvements to frontage roads and ramps from the I-75/Sawgrass Expressway interchange to the I-595/I-95 interchange, for a total project length along I-595 of approximately 10.5 miles and a design and construction cost of approximately \$1.2 billion. The project improvements will be implemented as part of a PPP with I-595 Express, LLC, a subsidiary created by ACS Infrastructure Development, which was awarded the contract to be the concessionaire to design, build, finance, operate, and maintain (DBFOM) the project for a 35-year term. The DBFOM project delivery was chosen as a result of initial findings that the project would take up to 20 years to complete if funded in the traditional way. The Florida DOT (FDOT) found that if it could deliver the project with the DBFOM method that it could reap considerable cost savings over the life of the project. In addition, it would reach the desired traffic capacity 15 years sooner than if traditional methods were used. FDOT will provide management oversight of the contract; install, test, operate and maintain all SunPass tolling equipment for the reversible express lanes; and set the toll rates and retain the toll revenue.

3.9.2 Complexity

FDOT has been challenged to find the right level of oversight for the project. The process has been a learning experience for both FDOT and the concessionaire. One lesson learned is that it is very important for the concessionaire to partner with local companies to learn the local culture and the processes of involved agencies (see Figure 3.9).

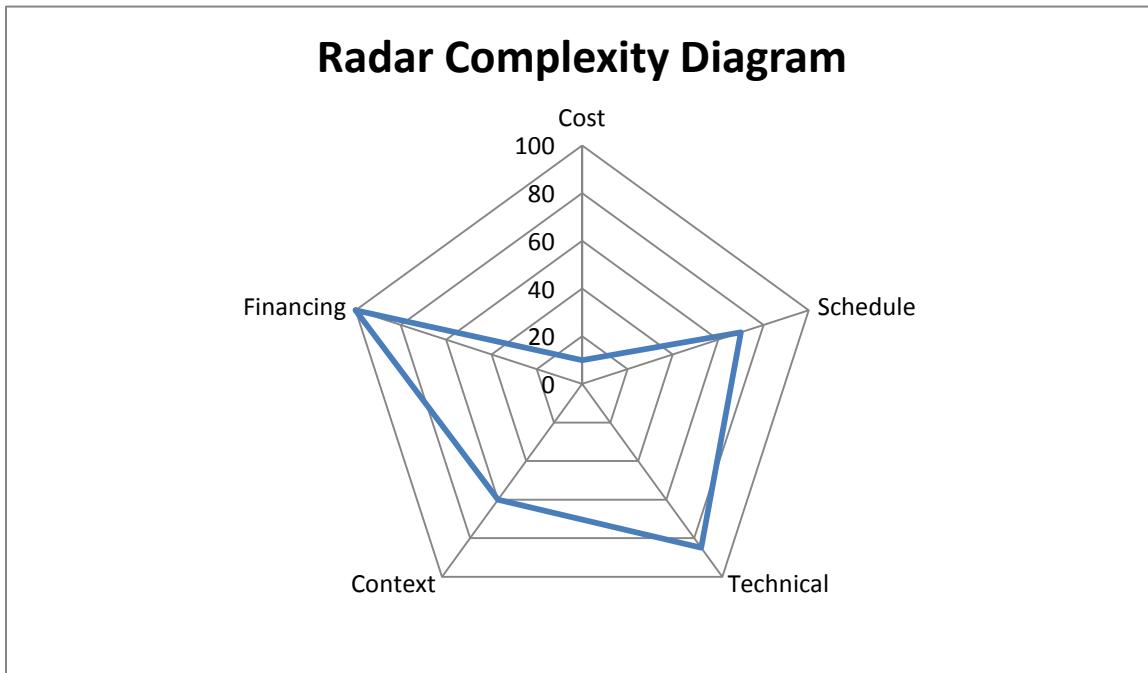


Figure 3.9. I-595 Corridor complexity map.

3.9.3 Primary Tools

The primary tools used for the project include assembling an owner-driven project team, preparing a finance plan and early cost model, colocating the team, evaluating flexible financing, and establishing a public involvement plan.

3.10 InterCounty Connector Project

3.10.1 Information

The InterCounty Connector project consists of 18 miles of construction on a new alignment and incorporates some reconstruction of interchanges and existing corridor that intersects the new project. The purpose of the project is to provide a limited access, multimodal facility between existing and proposed development areas in Montgomery and Prince George's counties in Maryland. Currently, the project is broken out into five separate construction contracts and 47 separate environmental stewardship and mitigation contracts. The total anticipated cost is around \$2.566 billion with \$109 million accounting for the environmental contracts. The initial environmental studies began in 2004, and the first construction segment of the project started in November 2007. Only three of the five construction contracts have been fully let, all using DB procurement. Each segment is scheduled to open incrementally, and the currently contracted projects are expected to be finished in late 2011. The final two contracts are yet to be determined for letting periods and anticipated completion. Along with the 18 miles of mainline construction, the project has slated for completion nine interchanges, one intersection, two bridges, 4 miles of existing highway reconstruction, and 4.9 miles of resurfacing. The project is using multiple funding sources and will be part of Maryland's tolling network upon completion. Grant Anticipation Revenue Vehicle (GARVEE) bonds, Maryland DOT pay-as-you-go program funds, special federal appropriations, Maryland Transportation Authority bonds, Maryland general fund transfers, and a Transportation Infrastructure Finance and Innovation Act (TIFIA) loan are all sources of funding that are being used for this project.

3.10.2 Complexity

The use of the DB approach and multiple separate contracts as well as construction through an environmentally sensitive area make this project complex (see Figure 3.10). An extensive financial plan is required, and multiple funding sources are being used. Immense scope, multiple stakeholders and funding sources, and 50-year-old original project discussions are issues that the owner lists as reasons for treating it as a complex project.

For this project, there was discrepancy between the complexity rank of each dimension and the score of the overall complexity for the dimensions (see Table 3.1).

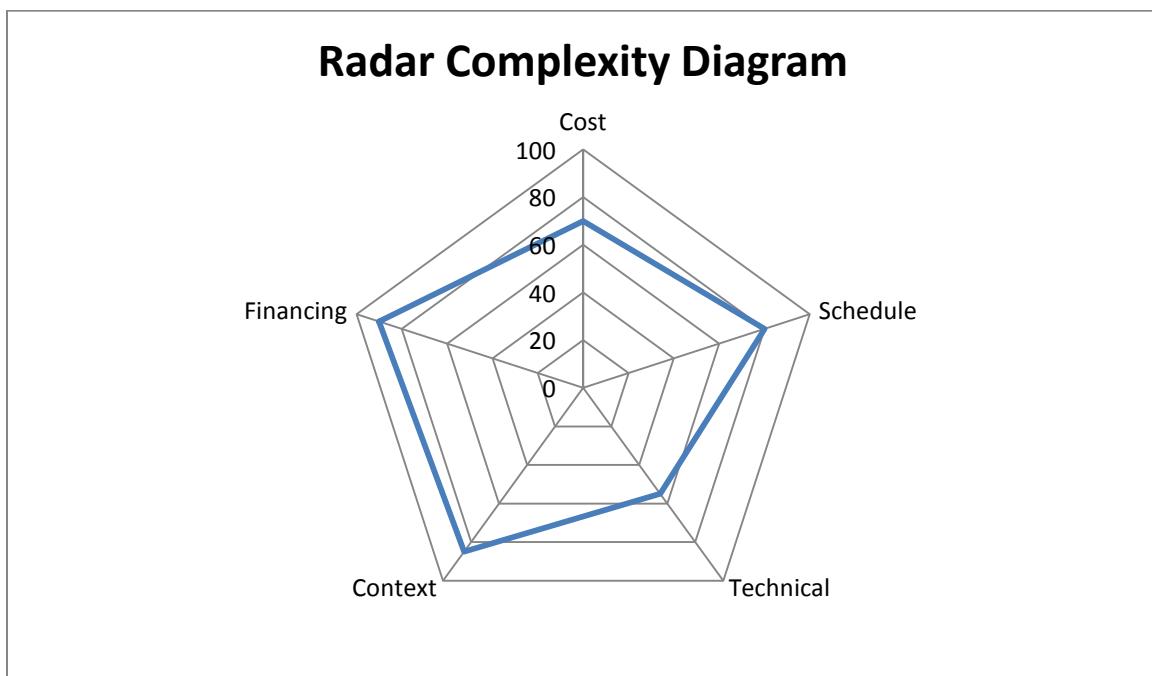


Figure 3.10. InterCounty Connector complexity map.

Table 3.1. InterCounty Connector Complexity Rank and Score Comparisons

Dimension	Rank	Complexity Score
Cost	1	70
Schedule	2	85
Technical	4	55
Context	3	85
Financing	5	85

3.10.3 Primary Tools

The primary tools used for the project include preparing a finance plan and an early cost model, identifying critical permit issues, and evaluating flexible financing.

3.11 James River Bridge/I-95 Richmond Project

3.11.1 Information

The James River Bridge/I-95 Richmond project consists of the restoration of the 0.75-mile-long James River Bridge on I-95 through the central business district of Richmond, Virginia. The project consisted of six lanes designed and built in 1958 to carry one-third of the 110,000 vehicles per day that it carried when it was rebuilt in 2002. The contractor proposed to use preconstructed composite units, which consisted of an 8.7-inch concrete deck over steel girders

fabricated in a yard off site. Crews cut the old bridge spans into segments, removed them, and prepared the resulting gaps for the new composite unit; they then finished the process by setting the new prefabricated unit in place overnight.

The case study project includes

- 0.75 miles of Interstate bridge restoration,
- Improvements on Route 1 that included widening to six lanes and signalization,
- High mast lighting system,
- Robust public information program, and
- Agreements with Richmond Downtown Chamber of Commerce (DCoC).

3.11.2 Complexity

The project was regarded as complex because of construction scheduling restrictions due to location, volume of traffic, and potential impact on the public (see Figure 3.11). The visibility of the project was extreme: the office was located in the immediate proximity of both the state legislature offices and the Virginia DOT central office. Also implementation of an untried construction method and an untried incentive and disincentive contract structure was complex.

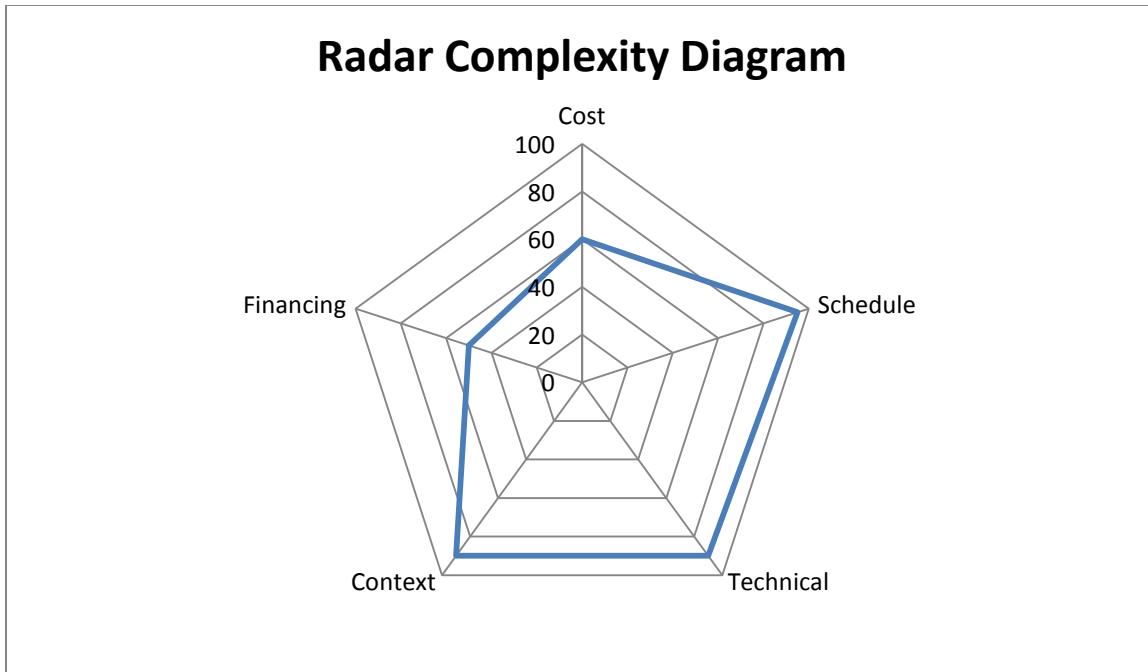


Figure 3.11. James River Bridge/I-95 Richmond complexity map.

3.11.3 Primary Tools

The primary tools used for the project include defining project success by each dimension as required, selecting a contracting method based on project outcomes, and establishing flexible design criteria.

3.12 Lewis and Clark Bridge Project

3.12.1 Information

The Lewis and Clark Bridge spans the state line between Washington State and Oregon, providing a link for motorists between the states. The cost of the deck replacement was split evenly by both states. The bridge is 5,478 feet in total length with 34 spans carrying 21,000

vehicles per day. The original bridge was built in 1929, and at the time of construction, it was the longest and highest cantilever steel truss bridge in the United States. To extend the life of the existing bridge by 25 years, a full-depth precast deck replacement was designed and executed. The final total value of the project is about \$24 million.

3.12.2 Complexity

The Lewis and Clark Bridge is the only link between Washington State and Oregon within at least a 1- hour distance, and as such, initiated the complexity of the project from the context dimension. The owner had to seek solutions to minimize traffic impact. User benefits were the major driver to go with a more-complex construction strategy, such as using an incentive contract, which the owner had not experienced before, night and weekend full closure of the bridge, and precast deck replacement (see Figure 3.12).

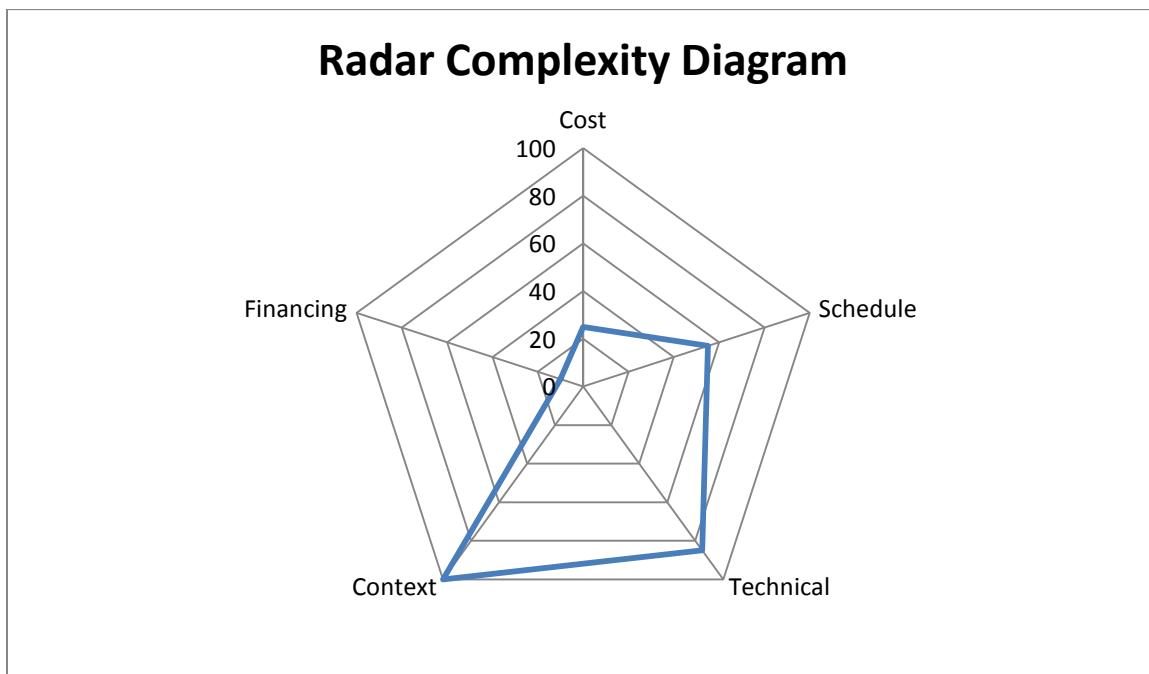


Figure 3.12. Lewis and Clark Bridge complexity map.

3.12.3 Primary Tools

The primary tools used for the project include defining project success by each dimension as required, selecting a contracting method based on project outcomes, and establishing flexible design criteria.

3.13 Louisville–Southern Indiana Ohio River Bridge Project

3.13.1 Information

The Ohio River Bridges project in Louisville, Kentucky, and southern Indiana is a complex project entering the final stages of the design phase. It consists of two long-span river crossings across the Ohio River (one in downtown Louisville and one on the east side of the metro area), a new downtown interchange in Louisville, a new approach and a 4.2-mile-long highway on the Indiana side, a new east end approach on the Kentucky side that includes a 2,000-foot-long tunnel, and reconfiguration of the existing interchanges to improve congestion, mobility, and safety.

3.13.2 Complexity

The project is regarded as complex because of the very large scope of work, insufficient funds, undefined financing plans, several historic districts and neighborhoods, multiple jurisdictions, political and environmental issues, and requirements for ongoing public involvement. Design is virtually 100% complete, but estimated construction costs (\$4.1 billion) far exceed available funds. Construction schedule, procurement, contracting, and so on will depend on funding and financing plans currently under development (recommendations due 1/1/2011) (see Figure 3.13).

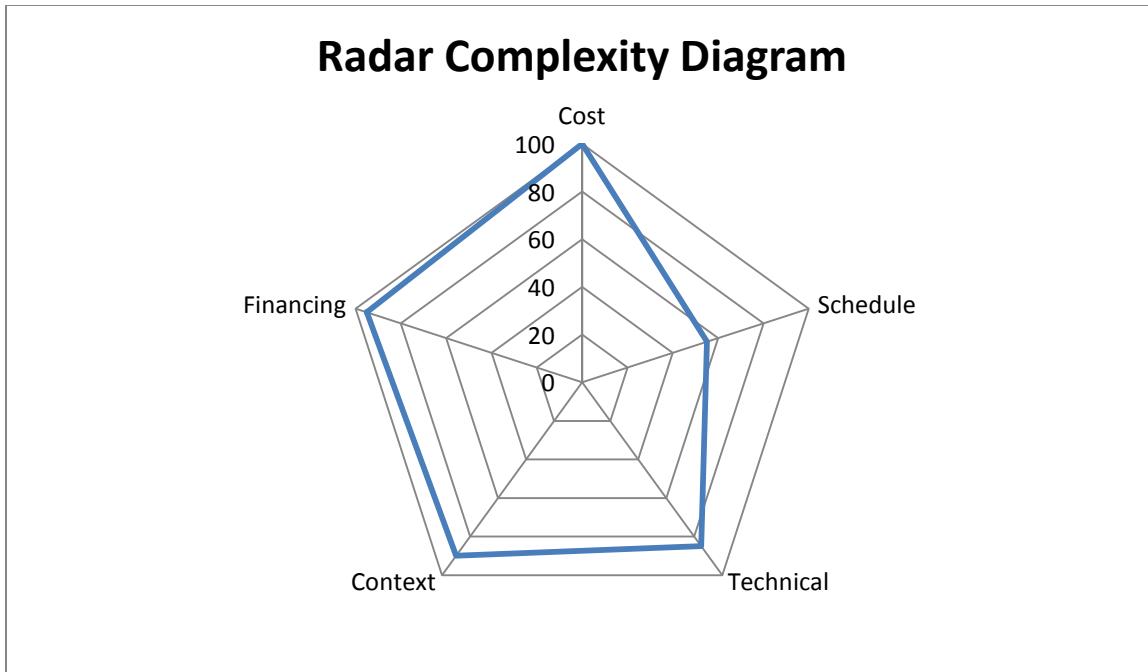


Figure 3.13. Louisville–Southern Indiana Ohio River Bridge complexity map.

3.13.3 Primary Tools

The primary tools used for the project included determining the required level of involvement in ROW and utilities, determining work package and sequence, and establishing a public involvement plan.

3.14 New Mississippi River Bridge Project

3.14.1 Information

The New Mississippi River Bridge project in St. Louis, Missouri, and East St. Louis, Illinois, is a complex project. It consists of building a new long-span, cable-stayed bridge with four lanes across the Mississippi River 1 mile north of the existing Martin Luther King Bridge. In addition, the project includes a new North I-70 interchange roadway connection between the existing I-70

and the new bridge, with further connections to the local St. Louis street system at Cass Avenue. On the Illinois side, the project includes a new I-70 connection roadway between the existing I-55/I-64/I-70 Tri-Level Interchange and the main span. In addition, significant improvements will be made at the I-55/I-64/I-70 Tri-Level Interchange in East St. Louis, which will connect to I-70. The 1,500-foot-long main span will be the second-longest cable-stayed bridge in the United States when completed.

3.14.2 Complexity

From the beginning, this project had several reasons for being considered a complex project, such as time and cost constraints, technical complications, large scope, railroad and utility coordination, and special appropriation funding (use it or lose it funding). Crash incidence near the existing bridge is three times the national average, and congestion on the bridge ranks among the 10 worst-congested corridors in the country, so redesign and expansion of capacity was critical. Severe traffic (capacity, safety, and mobility) conditions also made the schedule a priority. The original project plan had to be rescoped into viable phases given available funding and without sacrificing the overall project vision. The risk of cost and schedule overruns had to be mitigated to protect funding opportunities (see Figure 3.14).

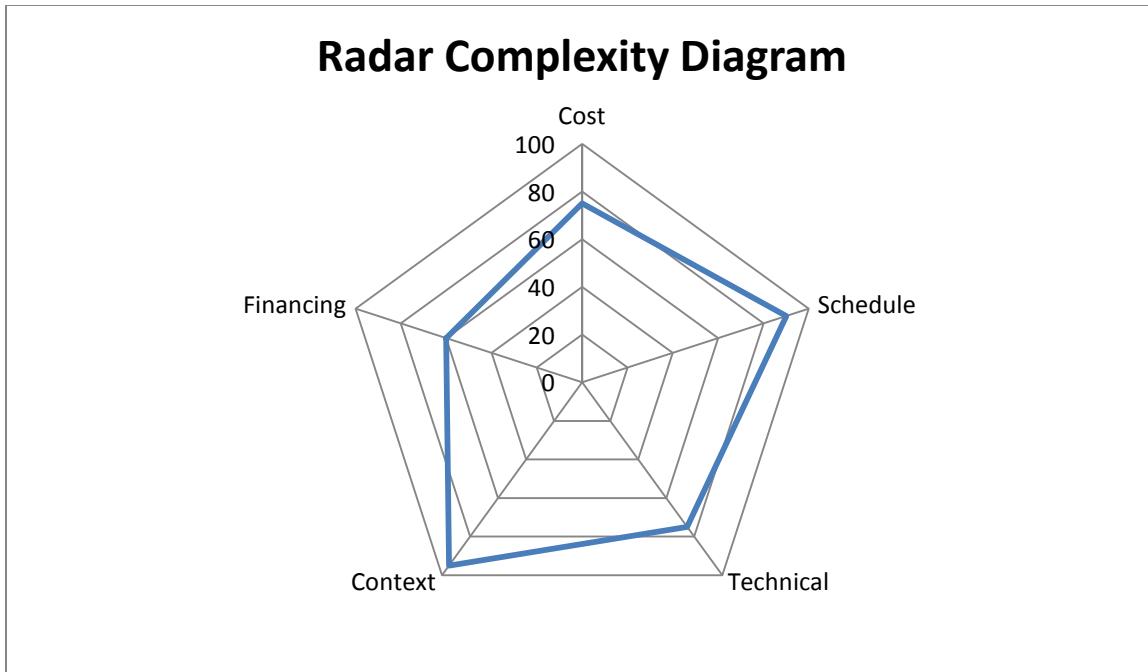


Figure 3.14. New Mississippi River Bridge complexity map.

3.14.3 Primary Tools

The primary tools used for the project include the design-to-budget approach, performing a comprehensive risk analysis, and colocating the team.

3.15 North Carolina Tollway Project

3.15.1 Information

In 2002, the North Carolina General Assembly created the North Carolina Turnpike Authority to respond to growth and congestion concerns in North Carolina. Two of the nine authorized projects include the Triangle Parkway and the Western Wake Parkway, which together compose the Triangle Expressway. These two projects combine for approximately 19 miles of new roadway on one side of Raleigh, North Carolina. These projects will be North Carolina's first experience with modern toll facilities. Both projects were initially advertised in 2007, and

completion is expected in 2011. The total awarded value of the project is approximately \$583 million.

3.15.2 Complexity

This is the first tollway in North Carolina. The schedule and finance dimensions are keys to this project. It is important to get the project open to start collecting toll revenue (Figure 3.15).

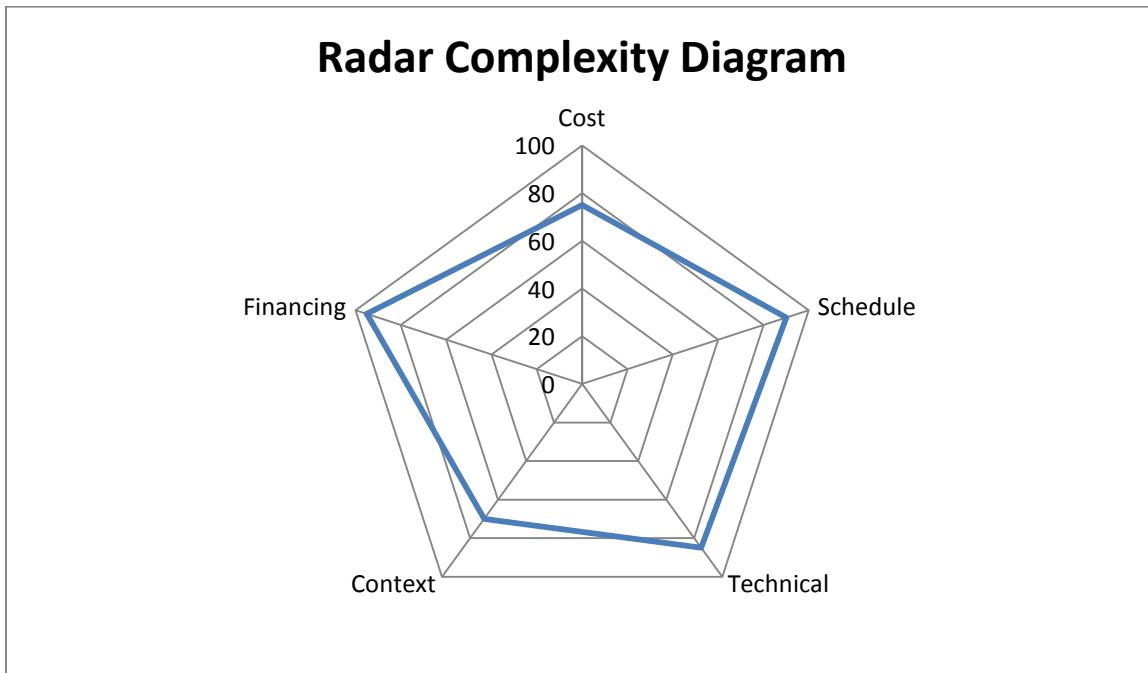


Figure 3.15. North Carolina Tollway complexity map.

3.15.3 Primary Tools

The primary tools used for the project include preparing a finance plan and an early cost model and establishing flexible design criteria.

3.16 Northern Gateway Toll Road Project

3.16.1 Information

The Northern Gateway Toll Road was the first toll road in New Zealand to be fully electronic, and the construction project was one of New Zealand's largest, most challenging, and most complex to date. It extends the four-lane Northern Motorway 7.5 km further north from Orewa to Puhoi through historically rich and diverse landscapes, steep topography, and local streams and provides an alternative to the steep two-lane winding coastal route through Orewa and Waiwera. The \$360 million extension of State Highway One (SH1) was constructed to provide a straight and safe drive between Auckland and Northland. The project was delivered by the Northern Gateway Alliance (NGA) comprised of Transit New Zealand, Fulton Hogan, Leighton Contractors, URS New Zealand, Tonkin & Taylor, and Boffa Miskell. The road, which opened in January 2009, has become a visual showcase of environmental and engineering excellence.

The Northern Gateway Alliance was appointed by the New Zealand Transport Authority (NZTA) to deliver a major realignment and extension of the Northern Motorway approximately 30 km north of Auckland, New Zealand. This was the largest single contract to date ever awarded by the NZTA. The NGA was formed by the NZTA in 2004 to design, manage, and construct the SH1 Northern Motorway extension. The project is being constructed through an area of very high environmental sensitivity and complex geology and topography.

3.16.2 Complexity

Funding was not in place at the start of the project and environmental requirements forced an early start of construction. Tunneling had not been done by the agency in decades, and the geotechnical situation was largely unknown. Consent condition was dependent on schedule. Immediate proof of starting construction was needed. Alliancing gave the option to start

construction after initial design concepts. Year by year extensions were given by the environmental court to proceed.

Funding was partly taken away before the start of construction. A business case was made for the Treasury, and the remaining money was borrowed in exchange for tolling rights for 35 years. The risk for this income was transferred to the Treasury. The alliance partners were aware that approval for this money was pending and the risk that the project could be halted would be shared (see Figure 3.16).

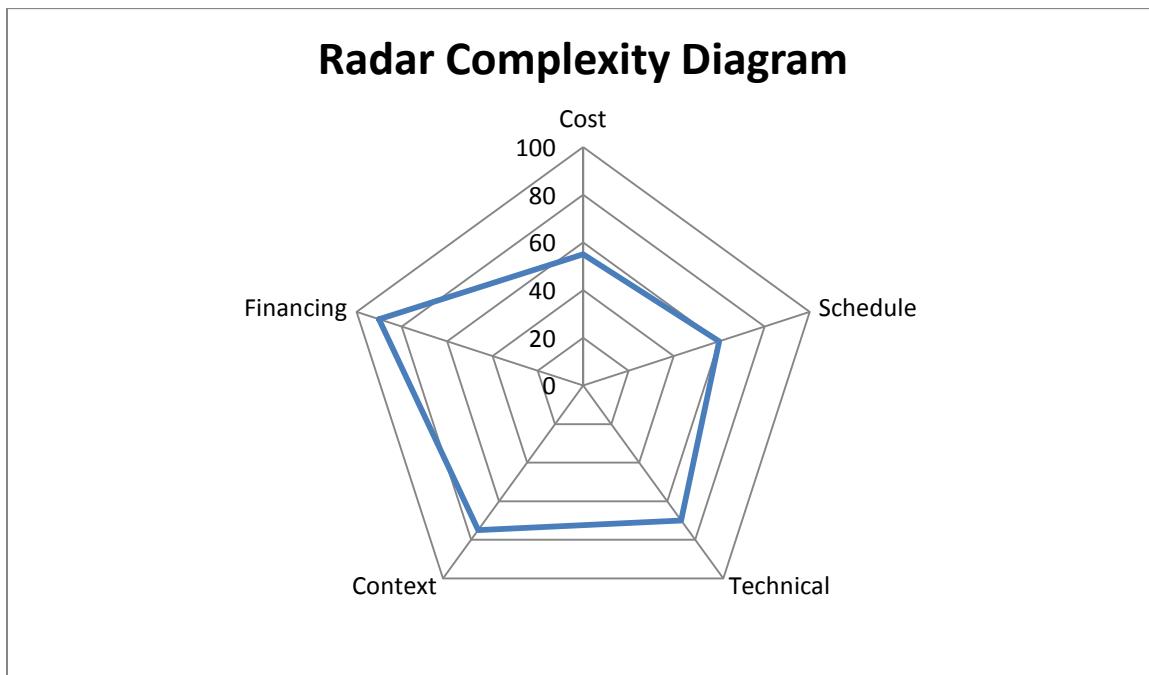


Figure 3.16. Northern Gateway Toll Road complexity map.

3.16.3 Primary Tools

The primary tools used for the project include defining project success by each dimension as required, selecting a contracting method based on project outcomes, and establishing a public involvement plan.

3.17 T-REX SE I-25/I-225 Project

3.17.1 Information

The Transportation Expansion Project (T-REX) (formerly the Southeast Corridor project) in Metro Denver, Colorado, consists of 17 miles of highway expansion and improvements to I- 25 from Logan Street in Denver to Lincoln Avenue in Douglas County and to I- 225 from Parker Road in Aurora to a newly configured I-25/I-225 interchange, as well as 19 miles of light rail developments along these routes. DB delivery was selected because of its ability to reduce the schedule and assign a single point of responsibility.

The original cost for the project was \$1.67 billion, which included the following:

- DB contract: \$1.2 billion,
- Maintenance facility: \$40–\$50 million,
- Siemens light rail vehicles: \$100 million, and
- ROW and administration: \$100 million.

3.17.2 Complexity

The project was considered complex because of the challenging work environment and the need to keep the highway open during the construction. Also, tracking of funding (highway versus traffic dollars) and the need to maintain bipartisan support created sensitive issues (see Figure 3.17). Political parties did not want to lose elections because the T-REX project had failed.

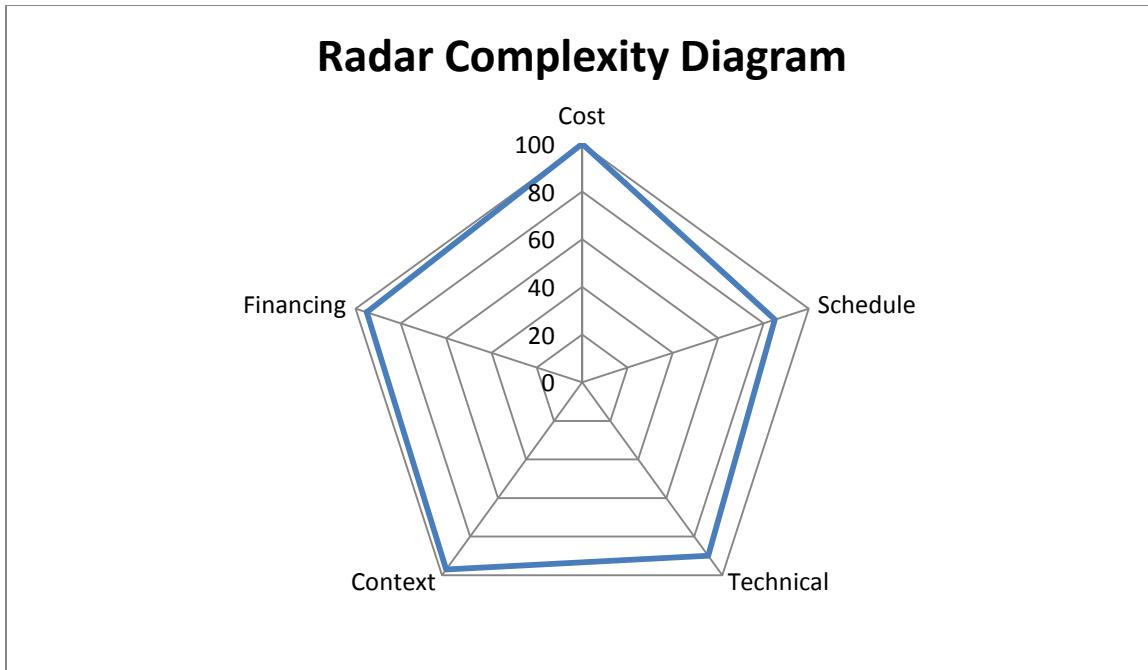


Figure 3.17. T-REX complexity map.

3.17.3 Primary Tools

The primary tools used for the project include selecting a contracting method based on project outcome, assembling an owner-driven project team, determining the required level of involvement in ROW and utilities, and establishing a public involvement plan.

3.18 TX SH-161 Project

3.18.1 Information

The Texas State Highway 161 (TX SH-161) project entails construction of an 11.5-mile-long north-south tollway and frontage roads midway between Dallas and Fort Worth. The project will be built in phases with an overall construction cost of approximately \$1 billion. The southern terminus of the project is at I-30. The project runs north with a full direct connector interchange

with I-20 and connects to the existing TX SH-161 on the north end with an interchange at TX SH-183. The case study project includes four phases and at least six projects.

Complexity

This project was complex because of the magnitude, multiple sources of financing, context (political influences), accelerated scheduling requirements, environmental concerns, and railroad involvement (see Figure 3.18).

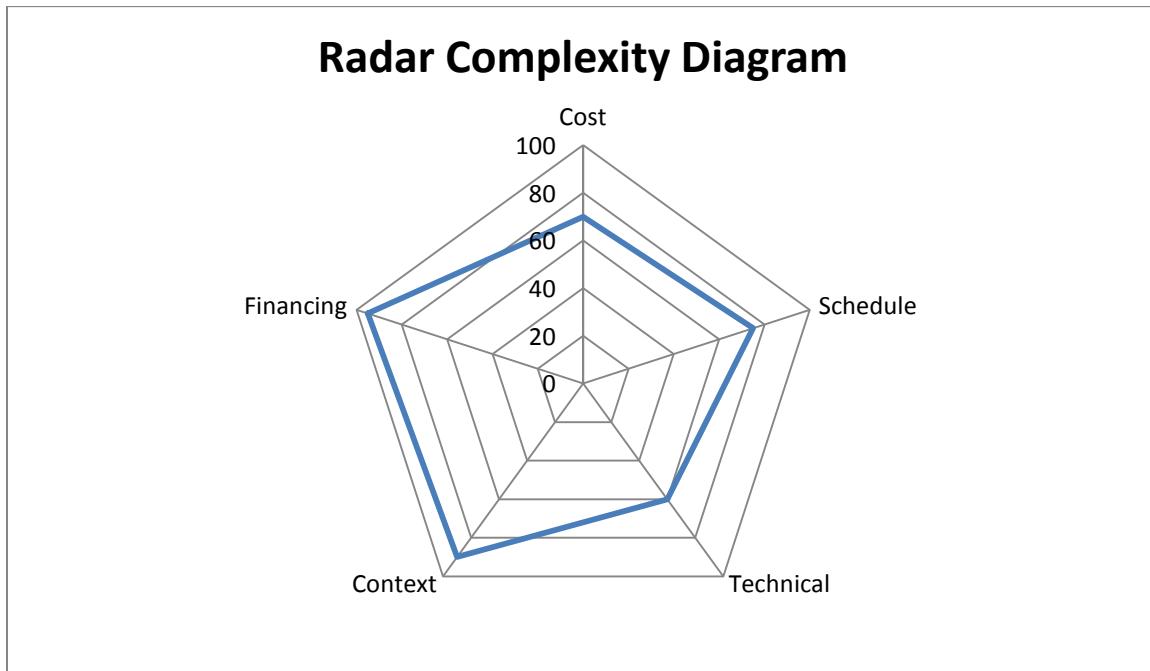


Figure 3.18. TX SH-161 complexity map.

3.18.3 Primary Tools

The primary tools used for the project include defining project success by each dimension as required, incentivizing critical project outcomes, and establishing a public involvement plan.

CHAPTER 4

Analysis

The documentation and analysis of the case studies enabled the research team to identify critical success factors for each case. This analysis included integrating the knowledge acquired from the case studies into the knowledge framework developed during the literature review created during Phase 1. The goal was to find the critical project management practices or strategies that led to success on the case study projects.

To facilitate the analysis, a table of the projects and the identified tools was developed. This table has undergone several iterations to categorize the tools into similar categories. The tools fall into two categories: project development (Table 4.1) and project execution (Table 4.2).

Table 4.1. Project Development Tools Identified by Case Study Projects

Project	Capital Beltway	Detroit River International Crossing	Doyle Drive	Green Street	Heathrow T5	Hudson-Bergen Light Rail Minimum Onerable Segment	I-40 Crosstown	I-95 New Haven Harbor Crossing Corridor Improvement Program	I-595 Corridor	Intercounty Connector	James River Bridge/ I-95 Richmond	Lewis and Clark Bridge	Louisville Southern Indiana Ohio River Bridge	New Mississippi River Bridge	North Carolina Toll way	Northern Gateway Toll Road	T-REX SE I-25/I-225	TX SH161
Tool																		
Development (executive level)																		
Define project success by each dimension, as required	X		X	X	X		X	X	X	X	X			X	X	X	X	X
Select contracting method based on project outcomes	X	X	X	X	X			X		X	X			X	X	X	X	X
Assemble owner-driven project	X	X	X	X	X		X	X	X	X	X			X	X	X	X	X

team																	
Prepare finance plan and early cost model	x		x	x			x	x	x	x		x	x	x	x		
Define political action plan	x	x	x			x		x		x	x	x	x	x	x	x	

Table 4.2. Project Execution Tools Identified by Case Study Projects

Project	Capital Beltway	Detroit River International Crossing	Doyle Drive	Green Street	Heathrow T5	Hudson-Bergen Light Rail Minimum Operable Segment	I-40 Crosstown	I-95 New Haven Harbor Crossing Corridor Improvement Program	I-595 Corridor	Intercounty Connector	James River Bridge/ I-95 Richmond	Lewis and Clark Bridge	Louisville Southern Indiana Ohio River Bridge	New Mississippi River Bridge	North Carolina Toll way	Northern Gateway Toll Road	T-REX SE I-25/I-225	TX SH161
Tool																		
Execution (project team)								x	x	x	x		x	x	x	x	x	
Incentivize critical	x		x	x													x	

Project	Capital Beltway	Detroit River International Crossing	Doyle Drive	Green Street	Heathrow T5	Hudson-Bergen Light Rail Minimum Operable Segment	I-40 Crosstown	I-95 New Haven Harbor Crossing Corridor Improvement Program	I-595 Corridor	Intercounty Connector	James River Bridge/ I-95 Richmond	Lewis and Clark Bridge	Louisville Southern Indiana Ohio River Bridge	New Mississippi River Bridge	North Carolina Toll way	Northern Gateway Toll Road	T-REX SE I-25/I-225	TX SH161
project outcomes																		
Develop dispute resolution plan	x	x	x	x				x	x	x	x				x	x		
Perform comprehensive risk analysis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Identify critical permit issues	x	x	x		x		x		x	x	x	x	x	x	x	x	x	x
Evaluate applications of off-site					x		x			x	x				x			

Project	Capital Beltway	Detroit River International Crossing	Doyle Drive	Green Street	Heathrow T5	Hudson-Bergen Light Rail Minimum Operable Segment	I-40 Crosstown	I-95 New Haven Harbor Crossing Corridor Improvement Program	I-595 Corridor	Intercounty Connector	James River Bridge/ I-95 Richmond	Lewis and Clark Bridge	Louisville Southern Indiana Ohio River Bridge	New Mississippi River Bridge	North Carolina Toll way	Northern Gateway Toll Road	T-REX SE I-25/I-225	TX SH161
fabrication																		
Determine required level of involvement in ROW and utilities	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x
Determine work package and sequence			x	x			x		x	x	x	x	x	x	x	x	x	
Design to budget												x		x	x	x	x	
Colocate team								x	x			x	x	x	x	x		

Project		Capital Beltway	Detroit River International Crossing	Doyle Drive	Green Street	Heathrow T5	Hudson-Bergen Light Rail Minimum Operable Segment	I-40 Crosstown	I-95 New Haven Harbor Crossing Corridor Improvement Program	I-595 Corridor	Intercounty Connector	James River Bridge/ I-95 Richmond	Lewis and Clark Bridge	Louisville Southern Indiana Ohio River Bridge	New Mississippi River Bridge	North Carolina Toll way	Northern Gateway Toll Road	T-REX SE I-25/I-225	TX SH161
Establish flexible design criteria	x	x		x		x			x	x	x	x	x		x	x	x	x	
Evaluate flexible financing	x	x	x			x			x	x	x	x	x		x	x	x	x	
Develop finance expenditure model	x		x				x	x	x				x	x	x	x	x		
Establish public involvement plan	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	

Note: ROW = right-of-way.

The tools in the project development category would typically be implemented at an executive level and would need to be started at the very beginning of project development. Many of these tools serve as a basis for decisions that need to be made throughout the project life cycle. The project execution category includes tools that happen later in the project life cycle during execution of the project. Execution can be started in planning and continue through design and construction of the project. Eventually, all of these tools may also appear in the operation phase (see Table 4.3).

Table 4.3. Identified Tools by Number of Case Study Projects and Dimensions

Project	Count	Dimension
Tool		
<u>Development (executive level)</u>		
Define project success by each dimension as required	15	All
Select contracting method based on project outcomes	13	Technical, Finance, Schedule
Assemble owner-driven project team	15	Context, Technical

Prepare finance plan and early cost model	11	Finance, Cost
Define political action plan	12	Context
<u>Execution (project team)</u>		
Incentivize critical project outcomes	12	All
Develop dispute resolution plan	10	All
Perform comprehensive risk analysis	17	All
Identify critical permit issues	15	All
Evaluate applications of off-site fabrication	5	Technical, Schedule, Cost
Determine required level of involvement in ROW and utilities	15	Technical, Context, Cost
Determine work package and sequence	10	Technical, Schedule
Design to budget	3	Technical,

		Cost
Colocate team	6	Technical
Establish flexible design criteria	13	Technical
Evaluate flexible financing	11	Finance
Develop finance expenditure model	8	Finance
Establish public involvement plan	16	Context

Conducting a count of the number of times the tools are used in the case study projects (see Table 4.3) revealed that a majority of the tools are used in a large number of these projects. The tools that were identified also represent each of the five dimensions, which confirm the migration of complex-project management from three to five dimensions. Each of the tools identified has specific implementation techniques that were found through the case studies.

CHAPTER 5

Conclusions

The major objective of the case study data collection and analysis was to identify tools that can be effectively implemented to manage complex transportation projects. From the 18 case studies, the team identified five project development tools and 13 project execution tools that were found in a plurality of the cases studied. Brief examples of each of these tools are provided below.

More-detailed explanation and keys to effective use of these tools will be described in the R10 guide and workshop series.

5.1 Project Development Tools

The project team identified five project development tools that were used on the majority of the complex projects to effectively manage overarching degrees of complexity that were not attributable to only one specific dimension of complexity during the execution phase.

Define Project Success by each Dimension as Required

- Integrate identified project success factors into a comprehensive risk analysis and mitigation plan at the execution phase. In other phases, make certain that risks affecting critical project success factors are identified, analyzed, and mitigated through a formal, integrated process that includes procurement, design, contracting, political action, public relations, and other strategies.
- Defining project success needs to account for feasible project outcomes, given budget and financing realities. The project team needs to manage expectations of indirect stakeholders and define achievable outcomes within funding constraints.

- The project team needs to incorporate design, context, and funding and financing constraints into feasible project duration, completion date, and cost contingencies, given project characteristics.

Select a Contracting Method that is based on Project Outcomes

- Calculate road user costs and translate into cost of schedule delay or acceleration, which can be included in contracting language.
- Calculate cost of capital or other cost model and include cost-sharing and cost-saving processes, such as the Alternative Technical Concept or contingency savings splits, into the contract language.
- Use comprehensive risk analysis and mitigation planning to identify potential sources of delay and cost overruns, which include politically powerful neighborhood groups, unions, local jurisdictions, state historical preservation office (SHPO), utilities, social equity and advocacy groups, environmental agencies and organizations, and work closely within the project team (owner, designer, and contractor) to develop contract language aimed at mutually beneficial outcomes, such as meeting disadvantaged business enterprises (DBE) goals, reducing the number of public complaints, gaining project approval ratings, reducing environmental incidence reports and loss time accidents, and any number of possible project outcomes.
- Recognize the large continuum of contracting and delivery options between formal low cost, open bid award, design-bid-build procurement and pure DB turnkey contracting. Any procurement or contracting method can be tailored to require prequalification of bidders, legal structure of proposers, or other partner requirements that add value to the

project. Reject the “liability of labels” (15) and choose innovative contracting and alternative delivery that meet the needs of the project.

Assemble Owner-Driven Project Team

- Director of DOT formally empowers designated project team to operate outside agency hierarchy.
- Project leader has flexibility to “handpick” team members.
- Project leaders have discretion to choose contractors, and consultants are selected by factors other than low-cost proposals.
- Owner agency sets project priorities. While understanding the needs of multiple stakeholders, the owner acts clearly in the best interest of the project and is not unduly influenced by self-interested demands and political power of any specific stakeholder group.

Prepare Finance Plan and Early Cost Model

- Understand available funds and establish scope, budget and schedule that are viable.
- Use cost models to phase the work to fit funding and cash flow.
- Develop mechanisms for frequent, real time cost and schedule updates to confirm validity of cost models.
- On complex projects, understand the reality that financing and funding availability determine cost, schedule, and scope decisions, rather than the reverse relationships that are standard for many agency projects.

- Develop a process for early contractor and vendor input using tools such as design-supply-build, construction management at risk, or DB delivery systems, contractor review boards, and Alternative Technical Concept proposals.
- Implement a process for getting “unsolicited proposals” into the project or program. Complex projects are aided by innovation, but highly standardized specifications and general requirements stifle innovation. Within reason, consider as many options as possible, even those which at first may appear unconventional.
- Sometimes the process of identifying cost models and financial plans will be steeped in uncertainty and result in unreliable, perhaps confusing, data, but the process of attempting to model costs is beneficial in identifying risks and establishing realistic contingencies and managing stakeholder expectations. Each complex project should attempt cost modeling if only to identify high risk (high uncertainty) areas and assign realistic contingencies.

Define Political Action Plan

- Work with legislators on required statutory changes needed to allow for flexibility in contracting and delivery tools so that project procurement can be tailored to the needs of complex projects.
- Develop neighborhood councils to facilitate dissemination of information.
- Expand comprehensive risk analysis and management programs to include identification and mitigation of potential political risks.
- Prepare thorough baseline documentation and comparative analysis to better defend project choices from political attacks. Politically motivated challenges can delay projects,

and proper documentation and ability to show due diligence and objective as well as inclusive decision making are keys to minimizing the delays.

- Establish a direct communication link between politically powerful stakeholders and project leaders, agency secretaries, or project administrators who can reliably and quickly disseminate information within the project partner organizations.
- Develop a working relationship with unions early in the process to facilitate DBE participation goals, schedule control, and so forth. Project labor agreements can be valuable in establishing expectations.

5.2 Project Execution Tools

The project team identified 13 project execution tools that were used on a plurality of the complex projects to effectively manage project-specific sources of complexity attributable to one or several specific dimensions of complexity during the execution phase.

Incentivize Critical Project Outcomes

- Incentivize contractor for social performance, which includes effective working relationships with local social justice advocacy groups.
- Incentivize contractor for environmental performance, which includes effective working relationships with environmental regulatory agencies and local environmental advocacy groups.
- Incentivize contractor for public involvement performance.
- Incentivize contractor or critical project partners, such as utility or railroad companies, for schedule performance. Pay for additional services as required to keep project moving.

- Incentivize contractor for cost performance.
- Incentivize contractor for safety performance.
- Incentivize contractor for traffic mobility performance.

Develop Dispute Resolution Plan

- Negotiate dispute resolution plans for neighborhood groups, U.S. DOT Section 4(f) signatories, and other indirect stakeholders.
- Integrate dispute resolution plan into a political action plan.
- Contractually stipulate the dispute resolution process between designer and owner if scope agreement issues arise.
- Prepare memorandum of agreement that all local jurisdictions are signatory to that elaborates a process for resolving disputes that does not increase cost or schedule risk.
- Work with designers and city and local review agencies on flexible approval processes if new or innovative design solutions are under consideration. Use mechanistic designs and nonstandard protocols to resolve conflicts or disagreements.

Perform Comprehensive Risk Analysis

- Implement risk analysis and mitigation plan at early stages of project. Risk analysis can be both formal and informal, but both must include some clear and concise assignment of responsibilities and assignment of designated resources.
- Use Crystal Ball software to establish contingencies for the project.
- Expand risk analysis to include context and financing issues, such as railroad, utilities, 4(f) issues, the National Environmental Policy Act of 1969, appropriations and capital bill allocation (use it or lose it funding), and effect of delays on private equity viability.

- Use outcomes of risk analysis to develop aggressive mitigation plans, which include the possibility of reallocating contingency within project segments or phases to prevent delays or cost increases.
- Bring in contractor group or construction specialty review board early in the project life cycle to offer input on means, methods, and material supply issues.
- Use expert panels and historical records to assign probabilities (qualitative or quantitative) to potential loss events and factor these probabilistic evaluations into prioritization and mitigation strategies.
- Integrate risk analysis and mitigation plan into critical project success factors. Identify risk events that would potentially prevent goal achievement and focus mitigation efforts on these potential adverse events.

Identify Critical Permit Issues

- Very early in the project life cycle, develop timelines for environmental, 4(f), and other critical regulatory reviews. Use flexible planning and design to minimize impact of permit issues, including ROW acquisitions.
- Amend design to avoid 4(f) issues or create de minimis impacts. The key is to understand potential 4(f) or environmental issues before committing to final alignment or other design issues.
- Develop flexible response mechanisms for permit issues when uncertainty is high (i.e., geotechnical and subsurface conditions, SHPO sites, and so forth).

Evaluate Applications of Off-site Fabrication

- Use off-site fabrication as a schedule control technique as site constraints allow.

- Work with designers and contractors to develop innovative off-site construction means and methods to minimize road closures, traffic delays, detour lengths, public disruption (i.e., noise, loss of access).
- Use standardized, replicated designs to the extent possible for “noncomplex” aspects of the project (i.e., approach spans, retaining walls, overpasses, bridge deck).
- Consider prefabrication for repetitive work reflecting auxiliary functions, such as pedestrian walkways, guardrails, and so forth.

Determine Required Level of Involvement in ROW and Utilities

- Offer to pay for additional design staff to assist railroads and utilities with design reviews or planning.
- To the extent possible, incorporate railroads and utilities as project partners (rather than project adversaries) and develop win-win solutions to issues involving potential delay of cost increase.

Determine Work Package and Sequence

- Develop scoping documents on the basis of high-certainty funding sources.
- Develop a contracting and procurement plan that is based partially on local contracting capabilities, available work force, bonding issues, and so on.
- Determine what work will be performed by owner agency forces (e.g., city crews, state highway administration quality and testing crews).
- Develop work sequencing and staging plans that are based on road closure and detour options, road user costs, local access issues, and so forth.

- Break down design segments into the largest possible packages that balance schedule gains from concurrent designs with resource demands created by the need for integration between owner and design teams.

Design to Budget

- Use project phasing and phased design and estimating to build those segments of the project that can be funded under current financing opportunities, while keeping future overall project goals in mind.
- Develop practical design guidelines to manage stakeholder expectations.

Colocate Project Team

- On multijurisdictional (i.e., bstate) projects, place a dedicated, empowered representative project team in a common location.
- Depending on the project delivery system used, consider incorporating the colocation strategy for DB partners or contracting team in later stages.

Establish Flexible Design Criteria

- Use flexible design criteria that minimize potential ROW, utility, and 4(f) conflicts.
- Create flexible designs through use of design exceptions and need-based review and approval processes.
- Use performance specifications.
- Use mechanistic designs.

- Implement procurement mechanisms that allow designers to work with major material suppliers and vendors early in the project life cycle.
- Use Alternative Technical Concept procurement.

Evaluate Flexible Financing

- Investigate use of GARVEE bonds.
- Advocate for flexible financing such as PPPs and design-build-operate-maintain-transfer hybrid forms of contracting.
- Phase project to leverage different sources of financing.

Develop a Finance Expenditure Model

- Model project cash flows and integrate into project phasing plan.
- Use resource-loaded project plans and network schedules to track expenditures and project cash needs.

Establish a Public Involvement Plan

- Start public involvement early in the planning phase to allow for self-detour planning.
- Retain public relations specialist to serve as point of contact.
- Host neighborhood meetings with open agendas and mechanisms for soliciting feedback (i.e., disposable cameras).
- Start on public communication plan very early in the planning process.

5.3 Communication and Dissemination Plan

The major project case studies were successfully conducted and have identified numerous tools, as described. The next tasks of the research plan involve developing a communication and

dissemination plan for effectively sharing the information gathered with the broadest possible audience. The primary means of communication and dissemination will be a complex-project management guide and a complex-management workshop to be developed and delivered in Tasks 6–12 of the SHRP 2 R10 project. In the guide and workshop, the effective complex-project management tools will be described and practical implementation guidance will be offered to facilitate diffusion of these practices into transportation organizations at the national, state, regional, and local levels.

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APPENDIX A

Case Studies Questionnaire

SHRP 2 R10 Advance Copy for Case Study Agencies Scheduled Date: _____

Structured Interview Questionnaire: Complex Case Study Project

Below are the various areas in which the interviewer will be asking questions. Please have any historic details on hand at the time of the interview. We greatly appreciate your support for this important project and will give you the opportunity to review and suggest corrections to the draft case study write-up prior to its inclusion in the final report.

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I. General Agency Information:

1. Name of Agency:
2. What type of organization do you work for?

Highway/Road Agency Rail/Commuter Transit Agency Airport Agency

Seaport/Marine Transportation Agency Other; Please describe:
3. What level of authority is your agency? National State/Province
 County/City/Local Other; Please describe:

II. Case Study Project Information:

1. Project name and location:
2. Project scope of work: If you have a standard version of this, please give it to the interviewer.
3. Original Total Awarded Value of project: \$ Final Total Value of project: \$ NOTE:
 can be approximate values
4. Date preliminary design contract awarded: Date project advertised: NOTE: can be
 approximate dates

Date final design contract awarded: Date construction/CMR contract awarded:

[Note: same if DB]

Original Project Delivery Period (including design) Final Project Delivery Period
(including design)

Explanatory notes:

5. Project delivery method used on this project:
6. Which of the following were reasons why your agency selected the delivery method used for this project? Check all that apply.

<input type="checkbox"/> Reduce/compress/accelerate project delivery period <input type="checkbox"/> Establish project budget at an early stage of design development <input type="checkbox"/> Get early construction contractor involvement <input type="checkbox"/> Encourage innovation <input type="checkbox"/> Facilitate Value Engineering <input type="checkbox"/> Encourage price competition (bidding process) <input type="checkbox"/> Compete different design solutions through	<input type="checkbox"/> Compete different design solutions through the proposal process <input type="checkbox"/> Redistribute risk <input type="checkbox"/> Flexibility needs during construction phase <input type="checkbox"/> Provide mechanism for follow-on operations and/or maintenance <input type="checkbox"/> Complex-project technical requirements <input type="checkbox"/> Complex-project environmental permitting requirements
---	---

<p>the proposal process</p> <p><input type="checkbox"/> Innovative financing</p> <p><input type="checkbox"/> Reduce life cycle costs</p>	<p><input type="checkbox"/> Complex-project traffic control requirements</p> <p><input type="checkbox"/> Complex-project financing requirements</p> <p><input type="checkbox"/> Complex-project political/public relations requirement</p>
--	--

7. Which of the above was the single most significant reason for the delivery method decision on this project?
8. Please explain the process that led you to the choice of the project delivery method for this project
9. Does this project have a post-construction revenue stream associated with it? Yes What kind? No
10. If the above is yes, did you consider including O&M in the contract for this project? Yes
 No what was the reason?
11. If decided not to include O&M in the project, what was the reason?

III. Cost factors: Please answer the following questions from a general perspective based on your experience.

1. In which project delivery phase did the cost factors apply?

Cost Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Contingency usage	<input type="checkbox"/>					
Risk analysis	<input type="checkbox"/>					
Estimate formation	<input type="checkbox"/>					
Owner resource cost allocation	<input type="checkbox"/>					
Cost control	.1.1.1.1.1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Optimization's impact on project cost	<input type="checkbox"/>					
Incentive usage	<input type="checkbox"/>					
Material cost issues	<input type="checkbox"/>					

User costs/benefits	<input type="checkbox"/>					
Payment restrictions	<input type="checkbox"/>					
Other issues	<input type="checkbox"/>					

2. Please identify the issues that contributed to the sources of complexity found within the cost factors below.

Cost Factors	Issues	Was this more complex than normal?
Contingency assignation (allocated/unallocated, percentages)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Risk analysis (formal, informal)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Estimate formation (outdated, unusable, probabilistic, conceptual)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Owner resource cost allocation (budget)		<input type="checkbox"/> Yes <input type="checkbox"/> No

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Cost Factors	Issues	Was this more complex than normal?
restrictions)		
Cost control		<input type="checkbox"/> Yes <input type="checkbox"/> No
Optimization's impact on the project cost (faster schedule, higher costs)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Incentive usage		<input type="checkbox"/> Yes <input type="checkbox"/> No
Material cost issues (price volatility)		<input type="checkbox"/> Yes <input type="checkbox"/> No
User costs/benefits		<input type="checkbox"/> Yes <input type="checkbox"/> No
Payment restrictions (ability to pay)		<input type="checkbox"/> Yes <input type="checkbox"/> No

3. For each of the cost factors that applied to this project, please indicate the tools used to satisfy them.

Cost Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Contingency usage		
Risk analysis		
Estimate formation		
Owner resource cost allocation		
Cost control		
Optimization impact on project cost		
Incentive usage		
Material cost issues		
User costs/benefits		
Payment restrictions		

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Cost Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Other issues		

Cost Dimension Impact (Check all that apply)	Impacted Project Scope	Impacted Project Design Details	Impacted Project Schedule	Impacted Project Financing	Impacted Project Delivery Method
Check the areas that were affected by the cost factors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Were there cost factors that had a particularly heavy impact on the final project? If yes, which ones and why?

List any other sources of cost complexity not discussed above:

IV. Schedule factors: Please answer the following questions from a general perspective based on your experience.

1. In which project delivery phase did the schedule factors apply?

A-25

Schedule Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Timeline requirements	.1.1.1.1.1.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Risk analysis	<input type="checkbox"/>					
Milestones	<input type="checkbox"/>					
Schedule control	<input type="checkbox"/>					
Optimization's impact on project schedule	<input type="checkbox"/>					
Resource availability	<input type="checkbox"/>					
Scheduling system/Software	<input type="checkbox"/>					
Work breakdown structure	<input type="checkbox"/>					

Schedule Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Earned value analysis	<input type="checkbox"/>					
Other issues	<input type="checkbox"/>					

2. Please identify the issues that contributed to the sources of complexity found within the schedule factors below.

Schedule Factors	Issues	Was this more complex than normal?
Timeline requirements (normal, accelerated)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Risk analysis (formal, informal)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Milestones		<input type="checkbox"/> Yes <input type="checkbox"/> No
Schedule control		<input type="checkbox"/> Yes <input type="checkbox"/> No

A-25

Schedule Factors	Issues	Was this more complex than normal?
Optimization's impact on the project schedule (ability to accelerate based on budget restrictions)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Resource availability (leveling, scheduling)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Scheduling system/Software (resource/cost loaded, Primavera, Suretrak)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Work breakdown structure		<input type="checkbox"/> Yes <input type="checkbox"/> No
Earned value analysis		<input type="checkbox"/> Yes <input type="checkbox"/> No

3. For each of the schedule factors that applied to this project, please indicate the tools used to satisfy them.

Schedule Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective

A-25

Schedule Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Timeline requirements		
Risk analysis		
Milestones		
Schedule control		
Optimization's impact on the project schedule		
Resource availability		
Scheduling system/Software		
Work breakdown structure		
Earned value analysis		

Schedule Dimension Impact (Check all that apply)	Impacted Project scope	Impacted Project Design Details	Impacted Project Cost	Impacted Project Financing	Impacted Project Delivery Method
Check the areas that were affected by the schedule factors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Were there schedule factors that had a particularly heavy impact on the final project? If yes, which ones and why?

V. Technical factors: Please answer the following questions from a general perspective based on your experience.

1. In which project delivery phase did the technical factors apply?

A-25

Technical Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Scope of the project	<input type="checkbox"/>					
Owner's internal structure	<input type="checkbox"/>					
Prequalification of bidders	<input type="checkbox"/>					
Warranties	<input type="checkbox"/>					
Disputes	<input type="checkbox"/>					
Delivery methods	<input type="checkbox"/>					
Contract formation	<input type="checkbox"/>					
Design method	<input type="checkbox"/>					

Technical Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Reviews/Analysis	<input type="checkbox"/>					
Existing conditions	<input type="checkbox"/>					
Construction quality	<input type="checkbox"/>					
Safety/Health	<input type="checkbox"/>					
Optimization impact construction quality	<input type="checkbox"/>					
Typical climate	<input type="checkbox"/>					
Technology usage	<input type="checkbox"/>					

2. Please identify the issues that contributed to the sources of complexity found within the technical factors below.

A-25

Technical Factors	Issues	Was this more complex than normal?
Scope of the project		<input type="checkbox"/> Yes <input type="checkbox"/> No
Owner's internal structure		<input type="checkbox"/> Yes <input type="checkbox"/> No
Prequalification of bidders		<input type="checkbox"/> Yes <input type="checkbox"/> No
Warranties		<input type="checkbox"/> Yes <input type="checkbox"/> No
Disputes		<input type="checkbox"/> Yes <input type="checkbox"/> No
Delivery methods (DBB, DB, CMR)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Contract formation		<input type="checkbox"/> Yes <input type="checkbox"/> No
Design method (limitations, specifications)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Reviews/Analysis (VE/VA, constructability reviews)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Existing conditions (structural, environmental)		<input type="checkbox"/> Yes <input type="checkbox"/> No

Technical Factors	Issues	Was this more complex than normal?
Construction quality		<input type="checkbox"/> Yes <input type="checkbox"/> No
Safety/Health		<input type="checkbox"/> Yes <input type="checkbox"/> No
Optimization (expediting schedule's impact on quality)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Typical climate		<input type="checkbox"/> Yes <input type="checkbox"/> No
Technology usage (3-D modeling, project management software)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Intelligent transportation systems (ITS)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Automation (robotic equipment)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Other issues		<input type="checkbox"/> Yes <input type="checkbox"/> No

A-25

3. For each of the technical factors that applied to this project, please indicate the tools used to satisfy them.

Technical Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Scope of the project		
Owner's internal structure		
Prequalification of bidders		
Warranties		
Disputes		
Delivery methods		
Contract formation		
Design method		
Reviews/Analysis		
Existing conditions		

A-25

Technical Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Construction quality		
Safety/Health		
Optimization's impact on construction quality		
Typical climate		
Technology usage		
Intelligent transportation systems (ITS)		
Automation		
Other issues		

Technical Dimension Impact	Impacted Project	Impacted Project Schedule	Impacted Project	Impacted Project

(Check all that apply)	Cost		Financing	Delivery Method
Check the areas that were affected by the technical factors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

List any other sources of technical complexity not discussed above:

VI. Context factors: Please answer the following questions from a general perspective based on your experience.

1. In which project delivery phase did the context factors apply?

Context Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Public	<input type="checkbox"/>					
Political	<input type="checkbox"/>					
Owner	<input type="checkbox"/>					

Context Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Jurisdictions	<input type="checkbox"/>					
Designers	<input type="checkbox"/>					
Maintaining capacity	<input type="checkbox"/>					
Work zone visualization	<input type="checkbox"/>					
Intermodal	<input type="checkbox"/>					
Social equity	<input type="checkbox"/>					
Demographics	<input type="checkbox"/>					
Public emergency services	<input type="checkbox"/>					
Land use impact	<input type="checkbox"/>					
Growth inducement	<input type="checkbox"/>					

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Context Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Land acquisition	<input type="checkbox"/>					
Local economics	<input type="checkbox"/>					
Marketing	<input type="checkbox"/>					
Cultural impacts	<input type="checkbox"/>					
Local workforce	<input type="checkbox"/>					
Utility coordination	<input type="checkbox"/>					
Railroad coordination	<input type="checkbox"/>					
Resource availability	<input type="checkbox"/>					
Sustainability goals	<input type="checkbox"/>					
Environmental limitations	<input type="checkbox"/>					

Context Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Procedural law	<input type="checkbox"/>					
Local acceptance	<input type="checkbox"/>					
Global/National economics	<input type="checkbox"/>					
Global/National incidents	<input type="checkbox"/>					
Unexpected weather	<input type="checkbox"/>					
Force majeure events	<input type="checkbox"/>					
Other issues	<input type="checkbox"/>					

2. Please identify the issues that contributed to the sources of complexity found within the context factors below.

Context Factors	Issues	Was this more complex than normal?
Public (expectations, acceptance)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Political (expectations, acceptance)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Owner (requirements)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Jurisdictions (process, requirements, expectations, acceptance)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Designers (coordination)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Maintaining capacity (access, traffic control plans)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Work zone visualization (variable message boards, signage)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Intermodal (rail, air, port)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Social equity (benefiting one class over another)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Demographics (impact)		<input type="checkbox"/> Yes <input type="checkbox"/> No

Context Factors	Issues	Was this more complex than normal?
Public emergency services (routes, police, fire, medical)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Land use impact (zoning)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Growth inducement		<input type="checkbox"/> Yes <input type="checkbox"/> No
Land acquisition (ROW)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Local economics (business access, effect)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Marketing (consultants, public notification, plans)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Cultural impacts		<input type="checkbox"/> Yes <input type="checkbox"/> No
Local workforce (experience and ability)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Utility coordination		<input type="checkbox"/> Yes <input type="checkbox"/> No
Railroad coordination		<input type="checkbox"/> Yes <input type="checkbox"/> No

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Context Factors	Issues	Was this more complex than normal?
Resource availability		<input type="checkbox"/> Yes <input type="checkbox"/> No
Sustainability goals (environmentally friendly objectives)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Environmental limitations (EIS)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Procedural law (permitting, acquisition process)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Local acceptance (use of alternate delivery methods, legal process)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Global/National economics		<input type="checkbox"/> Yes <input type="checkbox"/> No
Global/National incidents		<input type="checkbox"/> Yes <input type="checkbox"/> No
Unexpected weather		<input type="checkbox"/> Yes <input type="checkbox"/> No
Force majeure events		<input type="checkbox"/> Yes <input type="checkbox"/> No
Other issues		<input type="checkbox"/> Yes <input type="checkbox"/> No

3. For each of the context factors that applied to this project, please indicate the tools used to satisfy them.

Context Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Public		
Political		
Owner		
Jurisdictions		
Designers		
Maintaining capacity		
Work zone visualization		
Intermodal		
Social equity		

Context Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Demographics		
Public emergency services		
Land use impact		
Growth inducement		
Land acquisition		
Local economics		
Marketing		
Cultural impacts		
Local workforce		
Utility coordination		

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Context Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Railroad coordination		
Resource availability		
Sustainability goals		
Environmental limitations		
Procedural law		
Local acceptance		
Global/National economics		
Global/National incidents		
Unexpected weather		
Force majeure events		

Context Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Other issues		

Context Dimension Impact (Check all that apply)	Impacted Project Scope	Impacted Project Design Details	Impacted Project Cost	Impacted Project Schedule	Impacted Project Financing	Impacted Project Delivery Method
Check the areas that were affected by the context factors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Were there context factors that had a particularly heavy impact on the final project? If yes, which ones and why?

VII. Financing factors: Please answer the following questions from a general perspective based on your experience.

1. In which project delivery phase did the financing factors apply?

Financing Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Legislative process	<input type="checkbox"/>					
Uniformity restrictions	<input type="checkbox"/>					
Transition to alternate financing sources	<input type="checkbox"/>					
Project manager financial training	<input type="checkbox"/>					
Federal funding	<input type="checkbox"/>					
State funding	<input type="checkbox"/>					
Bond funding	<input type="checkbox"/>					
Borrowing against future funding	<input type="checkbox"/>					

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Financing Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Advance construction	<input type="checkbox"/>					
Revenue generation	<input type="checkbox"/>					
Vehicle miles traveled fees	<input type="checkbox"/>					
Cordon/Congestion pricing	<input type="checkbox"/>					
Monetization of existing assets	<input type="checkbox"/>					
Franchising	<input type="checkbox"/>					
Carbon credit sales	<input type="checkbox"/>					
Public–private partnerships	<input type="checkbox"/>					
Use of commodity-based hedging	<input type="checkbox"/>					
Global participation	<input type="checkbox"/>					

Financing Factors (Check all that apply)	Planning Phase	Procurement Phase	Design Phase	Construction Phase	Operations Phase	Remarks
Risk analysis	<input type="checkbox"/>					
Financial management software	<input type="checkbox"/>					
Other issues	<input type="checkbox"/>					

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2. Please identify the issues that contributed to the sources of complexity found within the financing factors below.

Financing Factors	Issues	Was this more complex than normal?
Legislative process (limitations on types of funding)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Uniformity restrictions (across jurisdictions)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Transition toward alternate financing sources		<input type="checkbox"/> Yes <input type="checkbox"/> No

Financing Factors	Issues	Was this more complex than normal?
Project manager financial training		<input type="checkbox"/> Yes <input type="checkbox"/> No
Federal funding (ARRA, TIFIA, GARVEE)		<input type="checkbox"/> Yes <input type="checkbox"/> No
State funds (STIP, state infrastructure bank, local tax revenue, commercial loans)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Bond funding (general obligation)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Borrowing against future funding		<input type="checkbox"/> Yes <input type="checkbox"/> No
Advance construction		<input type="checkbox"/> Yes <input type="checkbox"/> No
Revenue generation (tolls)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Vehicle miles traveled fees		<input type="checkbox"/> Yes <input type="checkbox"/> No
Cordon/Congestion pricing		<input type="checkbox"/> Yes <input type="checkbox"/> No
Monetization of existing assets		<input type="checkbox"/> Yes <input type="checkbox"/> No

Financing Factors	Issues	Was this more complex than normal?
Franchising		<input type="checkbox"/> Yes <input type="checkbox"/> No
Carbon credit sales		<input type="checkbox"/> Yes <input type="checkbox"/> No
Public–private partnerships		<input type="checkbox"/> Yes <input type="checkbox"/> No
Use of commodity-based hedging		<input type="checkbox"/> Yes <input type="checkbox"/> No
Global participation		<input type="checkbox"/> Yes <input type="checkbox"/> No
Risk analysis (formal, informal)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Financial management software		<input type="checkbox"/> Yes <input type="checkbox"/> No
Other issues		<input type="checkbox"/> Yes <input type="checkbox"/> No

3. For each of the financing factors that applied to this project, please indicate the tools used to satisfy them.

Financing Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Legislative process		
Uniformity restrictions		
Transition toward alternate financing sources		
Project manager financial training		
Federal funding		
State funding		
Bond funding		
Borrowing against future funding		
Advance construction		

A-25

Financing Factors (Check all that apply)	Tools	Relative Effectiveness 1-5 5=most effective
Revenue generation		
Vehicle miles traveled fees		
Cordon/Congestion pricing		
Monetization of existing assets		
Franchising		
Public-private partnerships		
Use of commodity-based hedging		
Global participation		
Risk analysis		
Financial management software		

Financing Dimension Impact (Check all that apply)	Impacted Project Scope	Impacted Project Design Details	Impacted Project Cost	Impacted Project Schedule	Impacted Project Delivery Method
Check the areas that were affected by the financing factors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Were there financing factors that had a particularly heavy impact on the final project? If yes, which ones and why?

List any other sources of financing complexity not discussed above:

VIII. Complexity ratings:

1. Please rank (1 to 5) the complexity of the following dimensions (Cost, Schedule, Technical, Context, and Financing) with 5 being the most complex. CANNOT make two or more equal.

Cost 1 2 3 4 5

Schedule 1 2 3 4 5

Technical 1 2 3 4 5

Context 1 2 3 4 5

Financing 1 2 3 4 5

2. Please indicate on the line with an “x” the score of the overall complexity for the dimensions.

Dimension	Scale		
	Minimal	Average	High
Cost	10 25 40 55 70 85 100		
Dimension	Scale		
	Minimal	Average	High
Schedule	10 25 40 55 70 85 100		

Dimension	Scale						
	Minimal	Average	High				
Technical	10	25	40	55	70	85	100
Dimension	Scale						
	Minimal	Average	High				
Context	10	25	40	55	70	85	100
Dimension	Scale						
	Minimal	Average	High				
Financing	10	25	40	55	70	85	100

Glossary

Cost Dimension

- Contingency usage: The reserve budget(s) (either allocated or unallocated) that is added to the overall cost estimate to account for the unknown risks.
- Risk analysis: Cost risk associated with a project that cannot be clearly identified and quantified through formal or informal analysis.

- Estimate formation: All of the different kinds of estimates required to be performed and the susceptibility to those costs varying from initial to final estimates.
- Owner resource cost allocation: The distribution of costs by the owner internally in order to make sure each area of project management has adequate finances to perform its operations.
- Cost control: All of the tools and methods used to control and manage costs throughout the project.
- Optimization's impact on the project cost: Trade-off between cost, schedule, and quality (i.e., reducing the duration of the project typically comes with a higher cost).
- Incentive usage: The use of incentives by the owner for early completion of the project.
- Material cost issues: The probability of the material costs changing because of market volatility.
- User costs and benefits: Cost trade-off between the transit user benefits of early completion with the increased construction costs required for accelerated construction of existing infrastructure.
- Payment restrictions: The ability of the owner to pay for performed work such as accelerated work performed by the contractor.

Schedule Dimension

- Timeline requirements: The timeline of the project (i.e., accelerated).
- Risk analysis: Schedule risk associated with a project that cannot be clearly identified and quantified through formal or informal methods.

- Milestones: Important deadlines during the project life cycle and their occurrence in a timely manner.
- Schedule control: All of the tools and methods used to control and manage schedule throughout the project.
- Optimization's impact on the project schedule: Trade-off between cost, schedule, and quality (i.e., accelerating the schedule may affect quality).
- Resource availability: The availability and uniformity of resources needed to maintain or alter the schedule.
- Scheduling system and software: The different types of systems and software available and mandated for the project, all with different capabilities.
- Work breakdown structure: The breakdown of the roles and responsibilities delegated to project participants.
- Earned value analysis: The tracking of scheduled work versus actual work performed.

Technical Dimension

- Scope of the project: The purpose of the project and generally what is going to be built to satisfy that purpose.
- Owner's internal structure: How the owner is set up to effectively manage the project (i.e., traditional hierarchy, matrix with project teams, etc.).
- Prequalification of bidders: The act of identifying and selecting qualified contractors and designers who are most capable of performing the requirements necessary for the project.
- Warranties: Provided by contractors that ensure the quality and guarantee that pieces of the project will remain adequate for a specified period of time.

- Disputes: Refers to disagreements between the parties and how they are to be handled.
- Delivery methods: The type of contracting approach used and how it is set up.
- Contract formation: The development of the contract responsibilities and specifications.
- Design method: The process and expectations stipulated by the owner for the project and the accuracy and quality required incrementally throughout the design phase. Also refers to considering the entire life of the project and the anticipated maintenance requirements over its life span.
- Reviews and analysis: Methods for maintaining accuracy and quality of the design and includes tools such as value engineering and analysis and constructability reviews.
- Existing conditions: Any structural limitations already in place that need to be accounted for so that the design satisfies the solution required by the owner.
- Construction quality: The value of the work that is being put in place by the contractors.
- Safety and health: Maintaining a workplace in which workers are made comfortable by all parties.
- Optimization's impact on the construction quality: Trade-off between cost, schedule, and quality (i.e., increasing quality requirements may increase costs).
- Typical climate: The typical climate where the project is located and the construction limitations presented by the area's typical climatic conditions.
- Technology usage: The technology specified to be used for project communications, such as specific project management software, building information modeling, and others.
- Intelligent transportation systems: Smart traffic systems for transportation projects. Their use needs to be analyzed as to their implementation into the project.
- Automation: The use of automated or robotic equipment for construction.

Context Dimension

- Public: Directly affected by and has the potential to affect the project from initial conception all the way through completion and well after turnover. The transportation project is for the public and their interests.
- Politicians: May be involved during the financing and need stages and are likely to be involved if the project is not perceived well by the public.
- Owner: Implements the project based on a need. Owners run and manage the project and have the most to lose or gain from the project's success or failure.
- Jurisdictions: All-encompassing group that includes any local, state, or federal organization such as the State Historic Preservation Office (SHPO), metropolitan planning organization (MPO), and Federal Highway Administration (FHWA). These entities may become involved because of regulations and limitations encountered by the project.
- Designer(s): Refers to the impact the contracted designer(s) have on the project.
- Maintaining capacity: Planning decision made by the owner such as lane closures, detours, and time of construction activities (i.e., nighttime, weekends, etc.).
- Work zone visualization: Based on maintaining capacity decisions and involves using the appropriate means to alert the public of alterations to normal traffic routes and the presence of construction activity.
- Intermodal: Refers to more than one mode of transportation and is a factor that must be realized when planning projects that involve, or affect, other modes of transportation.
- Social equity: Maintaining equality between all social classes that use and are affected by the project.

- Demographics: Outline the distribution of the population within an area. Alignment decisions may affect different demographics.
- Public emergency services: Include services that may have to be altered such as emergency routes taken by fire and medical personnel.
- Land use impact: A potential project may alter potential land use or the zoning plan of the area.
- Growth inducement: A potential project may spur growth.
- Land acquisition: Acquisitions may be hindered by the ability and process to acquire the portion(s) of land necessary for the project.
- Local economics: Influenced by growth inducement, alterations to land use, the rerouting of traffic away from business districts, and the creation of jobs from the project directly or indirectly.
- Marketing: Notification to the public of the project and its progress, particularly those matters directly affecting the public.
- Cultural impacts: The culture(s) of the area and the possible impact on the project.
- Local workforce: The skill and ability of the workers and the amount of qualified entities that can fulfill the project requirements.
- Utility coordination: All of the services necessary that may need to be moved and coordinated (i.e., electricity, gas, etc.).
- Railroad coordination: The coordination between the railroad agencies and the project.
- Resource availability: Availability of materials, labor, and equipment due to external factors (not because of cost, but scarcity).

- Sustainability goals: Materials or requirements to use environmentally friendly construction materials or desires by the owner to use alternative materials or methods.
- Environmental limitations: The type of environmental study that is necessary for the project, or any site-specific factors affecting the design and construction of the venture.
- Procedural law: The legal channels and limitations that should be followed for implementation of transportation projects such as permitting, zoning, and land acquisition. Procedural law is also the ability of an owner to use alternative delivery methods designated by law, such as design-build or construction manager at risk.
- Local acceptance: The ability, experience, or willingness to use different delivery options, if procedural law does not restrict the method, by the local parties that are likely to be involved with the project.
- Global and national economics: National and global economics that may externally affect the project.
- Global and national incidents: Any recent events that have occurred nationally or globally that may have an impact on the project, positively or negatively.
- Unexpected weather: Unforeseen conditions that are abnormal to typical conditions and therefore cannot be planned around.
- Force majeure events: Catastrophic events (i.e., tornado, hurricane, terrorism).

Financing Dimension

- Legislative process: The legal limitations placed on financing methods.
- Uniformity restrictions: The consistency seen among states for legislation and financing techniques.

- Transition toward alternative financing sources: The financing of complex projects compared to traditional project financing and the shift in financial planning.
- Project manager financial training: The education needed for project managers to understand financial methods.
- Federal funding: Provided by the national government; this funding is standard across the nation and derived from the annual transportation bill.
- State funding: Independently financed through the particular state where the project is taking place.
- Bond funding: The floating of bonds public and private entities may invest in to earn a return on investment on the project.
- Borrowing against future funding: Methods that allow the owner to borrow against future federal funding to undertake current projects.
- Advance construction: Similar to borrowing against future funding, but it allows states to independently raise the initial capital for a federally approved project and preserve their eligibility for future federal-aid reimbursement.
- Revenue generation: Any type of financing that is paid for by a generation of revenue from the infrastructure over a specified period of time.
- Vehicle miles traveled fees: User fees that charge the driver a specific cost for using the infrastructure.
- Cordon and congestion pricing: Reorienting traffic demand to less-congested areas and city centers. Entering the more-congested areas during certain hours requires some type of payment.

- Monetization of existing assets: After an existing road or bridge is brought up to some standard of quality, private entities are invited to take it over for a concession period, derive revenue from it, and then return it to the original standard before turning it over to the agency or another concessionaire.
- Franchising: Private companies are offered the opportunity to build and operate income-producing facilities, such as rest areas or fuel stations on the public ROW in return for a portion of the profits.
- Carbon credit sales: The carbon stored by trees and plants has a market value, and the credits can be sold to help finance the project.
- Public–private partnerships: Requires both public and private financing. The overall purpose for this category is to gain public access to private capital and use developers' capital to bridge the funding gap in a much needed piece of infrastructure and thus accelerate the delivery of its service to the traveling public.
- Use of commodity-based hedging: The ability to lock in the materials price at the earliest point when the required quantity is known.
- Global participation: The ability to take advantage of different procurement and capital project delivery cultures around the world. Each nation has its own set of business practices that create competition for financing of transportation projects.
- Risk analysis: Formal or informal analysis of the financing methods for the project.
- Financial management software: Any software used for managing the financial aspects of a project.

APPENDIX B

Case Study Summaries

Green Street Road Rehabilitation

Introduction

The sustainable “green street” road rehabilitation using recycled asphaltic concrete, portland cement concrete, and other waste rubble materials is a complex project because of limited resources, challenging soil conditions, and variable field conditions. In short, the project necessitated the use of design-supply-build principles that incorporate new innovative mechanistic design tools and a field validation system. The project investigated the potential to process rubble materials into high quality structural base course aggregate for roads. This report



Figure B.1. Map of Canada showing Saskatoon, SK.



Figure B.2. Map of Saskatoon, SK.

will detail the processes used to make decisions during the project's planning and procurement, execution, and operations phases. Figure B.1 shows the location of the city of Saskatoon, Saskatchewan (SK), Canada, and Figure B.2 shows a close-up of Saskatoon.

Project Planning and Procurement Phase

The planning and procurement phase started in April 2009 when the final design contract was awarded. The “go green” project was undertaken as a cooperative research and development effort between PSI Technologies, the Saskatchewan Ministry of Environment, the City of Saskatoon, and the University of Saskatchewan to develop innovative value added uses for recycled asphalt, portland cement concrete rubble, and other waste products. Saskatchewan road agencies have a significant reliance on high volume granular structural layers for the end product structural capacity in pavement design. As well, there is a need to increase the use of road substructure drainage systems because of an observed increased occurrence of groundwater effects on road life-cycle performance.

The go green project was established to integrate advanced scientifically based engineering methods, with advanced materials processing and road construction and asset management techniques to explicitly quantify the benefits of recycled material systems. The scope of the project included state-of-the-art recycle impact crushing integrated with advanced mechanistic laboratory characterization of the materials generated. Also involved in this project were the design and construction of field-test sections and field validation sites to monitor field performance across the various test sections. Ultimately, information received from these various test sections will be used to develop long term performance models and specifications. The project consisted of recycling of asphalt and portland cement concrete rubble into high value added materials. The project focused on development of high value substructure aggregates that are structurally superior to conventional aggregates. The superior qualities are attributed to careful processing and grading of the recycled materials. Included in this project were materials

recycling, mechanistic materials characterization and structural design, field construction of carefully engineered test sites, and mechanistic structural assessment in the field to validate mechanistic designs. To further complicate matters, many of the sites contain undrainable soils that lead to very moist subgrades. In addition, many of the granular systems become saturated over time resulting in significant failures of the structures. This means that the design of properly functioning granular systems is of critical importance (*I*).

Project Delivery Method

The project had an original project delivery period of 2 years, and the delivery method being used is RFP-design-supply-build. This delivery method was chosen because benefits included reducing the project delivery period, encouraging innovation, facilitating value engineering, and encouraging different design solutions that are based on the varying in situ conditions. In short, the complex technical requirements seemed best suited to this mode of delivery in that it provided the ability to address issues in an effective manner as the project progressed.

Cost Factors

Cost factors were taken into consideration during the planning for this project. Some uncertainty revolved around the new, unproven recycling technologies, cost control involving unknown field state conditions, incentive clauses to promote innovation, and overall uncertainty in the owner resource cost allocation. Risk analysis was important in the planning stage as well as in the design and construction phases. Overall, the risks were managed through the innovation testing and mechanistic design and analysis that were used. The original total awarded value of this project was \$10 million.

Schedule Factors

Schedules were prepared and included detailed timeline requirements, risk analysis for new unproven technology, and milestones to ensure the project would stay on time, within the cost, and that all the objectives would be met. A work breakdown structure was used for the integration of design-supply-build. Also, there was emphasis on environmental issues and creating an earned value analysis in this area.

Technical Factors

The planning phase for the design and engineering of this project was undertaken by PSI Technologies, which specializes in the engineering and construction of recycled road systems. This contract involved several designs.

Project Execution

Objective 1

The first objective task was to exhibit the ability to cost effectively process alternative rubble and other ancillary landfill waste materials to meet or exceed conventional granular aggregate specifications with minimal waste. PSI Technologies used state-of-the-art crushing and screening equipment to supply quality recycled rubble materials, as shown in Figure B.3. The process used resulted in a 40% to 70% reduction in quality aggregate cost, depending on the material specified.



Figure B.3. PSI Technologies' state-of-the-art impact crushing and recycling of asphaltic rubble material.

Objective 2

The objective task involved the validation of recycled rubble aggregates to exceed the mechanistic material constitutive properties of conventional City of Saskatoon granular base by 30%. The testing performed at this stage involved mechanistic laboratory characterization and in-field mechanistic structural testing measurements. The recycled aggregate showed improvement of between 30% and 50%. The mechanistic properties attained results in excess of a 200% improvement in mechanical behavior.

Objective 3

The objective task included applying various cold stabilization systems to recycled materials, to quantify the mechanistic-climate durability value added benefits. The research indicated that the cold stabilization systems using cement and asphalt emulsion can result in a wide range of end product material constitutive properties. However, the specific stabilization system must be properly selected to be compatible with the parent material.

Objective 4

This task was to show the results of using recycled materials in conventional road construction with conventional road construction equipment. In the summer of 2009, the City of Saskatoon constructed six recycled material test sections. As shown in Figure B.4, this is a typical finished compaction of SS-1 emulsion stabilized recycled asphalt pavement (RAP) black base. The results showed that recycled aggregate materials were effectively constructed with conventional construction equipment. Also, the risk of short term failure was reduced by improved construction efficiency.



Figure B.4. Finished compaction of SS-1 emulsion stabilized RAP black base.

Objective 5

In this task, structural asset management measures were performed and indicated that the recycle test section constructed exceeded the target structural designs and showed improvement over test sections constructed with conventional granular drainage rock. Research also shows that the recycled road structural systems will also provide improved life-cycle structural performance.

Objective 6

The use of recycled aggregate materials was tested in this task and resulted in positive results.

Cost-effectiveness is a key factor when examining recycled aggregate, and on the basis of the tests performed, it appears that the use of recycled aggregate enabled the City of Saskatoon to cost-effectively construct road structures with continuum drainage/structural subbase layers, as shown in Figure B.5. The use of recycled materials is also proposed to provide significant life-cycle performance benefits of the road over time.



Figure B.5. Placement of continuum recycled portland cement concrete drainage layer.

Objective 7

This task was to demonstrate that recycled materials are most cost-effective for road construction relative to conventional road aggregates. On the basis of the tests, the use of recycled materials

showed a cost savings of \$1.37 million in 2008, \$1.65 million in 2009, and a projected \$1.81 million in 2010.

The task focused on demonstrating the holistic benefits in terms of technical, economic, social, environmental, energy, and sustainability for the City of Saskatoon by using recycled rubble materials. The benefits included in the findings were a cost reduction in the manufacturing of recycled aggregates and also a reduction in material processing and transport energy by 50% to 70%. Also, reducing the haul within the city limits results in reduced road infrastructure damage.

Objective 8

This task was to provide evidence that the City of Saskatoon can adopt recycled aggregate for road rehabilitation projects. City construction crews implemented recycled materials into their road reconstruction operations. The crews implemented this so extensively that the PCC recycled aggregate supply was exhausted by mid-summer 2009.

Objective 9

The last objective task of the design and construction phase was to develop specifications on the basis of mechanistic performance for the production of recycled aggregate materials for the 2010 construction season.

Summary

All nine objectives in this project were exceeded when one considers the technical, social, economic, and environmental benefits. Some of the main results and benefits include

- Improved risk management of the project through the design-supply-build format;
- Significant cost savings;
- Improved road structural systems;
- More-sustainable infrastructure solutions for the City of Saskatoon;
- On the basis of preliminary estimates, effective use of recycled aggregates enabling the City of Saskatoon to structurally repair up to 30% more road surface for the given fixed budget;
- An improved life-cycle performance of the road structure;
- Achieving significant capital savings from constructing urban roads with the use of recycled materials;
- Improved structural integrity of the end product road system;
- Reduction in construction time, energy requirements, construction-generated emissions, and climate risk during construction; and
- Reducing the haul costs and road damage associated with aggregate haul by using recycled rubble aggregate that is already available and in-service within the city limits.

Observations of the Researcher

Greatest Challenges

- Project complexity related to poor soil conditions, limited funding, limited experience with recycling, and limited experience with the design-supply-build format, and
- Limited usage of in-field mechanistic evaluation techniques for design.

Successful Accomplishments

- Cost-effective solution,
- On-time delivery of the program of work,
- Successful design and construction under complex conditions, and
- Successful risk management.

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London Heathrow Airport Project

Introduction

The London Heathrow Terminal 5 (T5) project was one of the most complex projects ever undertaken in the United Kingdom and was the biggest construction site in Europe. The total

investment in the T5 project was £4.3 billion and took approximately 37 million person-hours to complete. Elements of the Terminal 5 project include the main terminal, two satellite terminals, air-traffic control tower, and connections to public transport, road works, rails, and tunnels. Once completed and delivered to the British Airport Authority (BAA), T5 will serve as the base for British Airways (BA) and finally fulfill its ultimate goal of enhancing the competitive advantages of London and the United Kingdom. This case study will introduce how this complex project was delivered.

Project Planning Phase

The construction of T5 was approved by the Secretary of State on November 20, 2001, after the longest public inquiry in British history (46 months).

Cost

The planning process itself cost nearly £63 million over a period of 14 years. This cost was borne mostly by the BAA and BA, the two main components of the project.

Technical

The actual T5 design work began in 1989 when the Richard Rogers Partnership won the bid.

Procurement Phase

Technical

The majority of the design work was finished by 2004, but the design of T5 experienced a series of radical changes that included incorporating new technologies, new environment and

transportation regulation requirements, end-user requirement variations, and unexpected events such as the emergence of terrorism. Those challenges have been highly stressed in the T5 design and guaranteed the delivery of the project as a landmark in engineering. Specifically, the overall design of the T5 can be broken down into the following components.

Terminal building

The most prominent component of T5 is the new terminal building and the new aircraft control tower. The main terminal building (housing Concourse A) is 396 m long, 176 m wide and 39 m high and contains 80,000 tonnes of structural steel, while a satellite building (housing Concourse B) adjoining this is 442 m long, 42 m wide, and 19.5 m high. The terminal contains 175 lifts, 131 escalators, and 18 km of conveyor belts for baggage handling. A strict ban was placed on any construction activity over 43 m high without prior arrangement to avoid interfering with Heathrow radar.

The roof design of T5 is especially notable because the “single wave” roof requires engineering genius to design and craftsmanship to produce and install. The final roof weighed a total of 18,500 tonnes and contained 22 steel box section rafters supported by 11 pairs of supporting abutments.

Air traffic control tower

The 87-m-high air traffic control (ACT) tower is an integral part of the T5 design in that this tower can significantly enhance the efficiency of the airport. The tower was in principal composed of two components, namely, the mast and the cone. The cone, which contains the control room, is supported on top of an 85-m-high, 4.6-m-diameter triangular steel mast anchored to the ground with three pairs of cable stays. The steel mast contains two lifts (one internal and one external) to provide access to the control room. The control tower was built in

12-m-high sections (the cone was raised by special jacks 12 m at a time). In April 2005, the new ACT tower was topped out, and in March 2005, the control tower was erected to its full height of 87 m and became operational during the third quarter of 2006.

Rail infrastructure development

Beyond the construction of the terminal itself, investment has been required to improve the transport infrastructure between the center of London and Heathrow Airport. Some of the major projects were the construction of tunnels for the extension of both the Heathrow Express and the Piccadilly Line.

Further, T5 has its own modern rail station located in the basement of Concourse A. The station has six rail platforms: two for the London Underground Piccadilly Line extension, two for the Heathrow Express extension, and two built for potential future rail expansion links to the west.

Road infrastructure development

Building the new T5 also required additional and improved road infrastructure, which included internal airside roads (completed in March 2005) and also connecting roads from the current road transport network. To construct the spur road connecting the M25 motorway, several tunnels had to be in place. Specifically, four tunnel-boring machines and 105,500 concrete tunnel-lining segments were used to create a network of nine separate tunnels that included the United Kingdom's seventh-longest road tunnel and four independent rail tunnels. Given the increased road traffic capability, a 4,000-space multistory car park for passenger use was built as well.

Automated people mover

The new T5 also incorporates a track transit system. This is an automated transportation system that transfers passengers between the main terminal and its satellite buildings. Transportation is provided by an automated people mover (APM). The APM consists of driverless trains that run on a dedicated subsurface guideway and that are capable of transporting passengers and their luggage. The personal rapid transit (the PRT) system has its own dedicated guideway from the business car park to T5. This £25 million system is the first of its kind in the world.

Storm water outfall tunnel

The storm water outfall tunnel (SWOT) forms the drainage and pollution control system for surface water runoff from the T5 campus to a reservoir 2 km to the south of the airport. At the southern end of the tunnel the runoff water passes through facilities that “clean” it before it is discharged.

The SWOT is also a fundamental component in enabling BAA to recycle the runoff water and reuse it in T5’s nonpotable water system. The tunnel and infrastructure have been designed so that in T5’s operational phase, clean water is pumped back up the tunnel and used in systems such as toilet flushes and heating systems. The SWOT comprises a single bore tunnel 4.1 km in length.

Project Execution

The construction phase included two subphases: (1) the construction of infrastructure and buildings and (2) the integration of systems and retail fit out of the buildings. The T5 supply chain included 80 first-tier, 500 second-tier, 2,000 third-tier, 5,000 fourth-tier, and 15,000 fifth-

tier suppliers. The work program involved four main activities—buildings, rail and tunnels, infrastructure, and systems—which were subdivided into 16 major projects and 147 subprojects. BAA used the long planning phase of T5 to create a radical improvement in project delivery; that is, a core team of senior managers and consultants was assembled to explore alternative practices, technologies, and ideas found in other industries and megaprojects and bring them together to create a new project delivery process. During this phase, the concept of “doing it differently” was the dominant theme to guide the delivery strategy. There was no previous experience of undertaking a project of this size and complexity and integrating a new facility on this scale into operations.

The whole life cycle, especially the extensive periods of planning and design, allowed T5’s participants to learn how to deliver such a complex project. BAA has learned how to deal with major construction risks in complex projects that include the delivery of the Heathrow Express project. Further, BAA conducted research specifically on problems associated with airport projects and identified poor systems delivery and integration during the final stage of project execution as a major reason why international airports fail to open on time. BAA concluded that transferring the risk to the contractor offered no real protection for the client. The only way to succeed on T5 was to change the “rules of the game” by establishing a new governance structure and commercial principles embodied in the T5 agreement. BAA was under the leadership of Sir John Egan, who instructed BAA to adopt successful lean production techniques found in automobile, retailing, and other high-volume industries to achieve an orderly, predictable, and replicable approach to project design. Despite operational problems that occurred when T5 was first launched, the T5 project achieved its design and construction performance targets for cost, time, quality, and safety.

In general, BAA has successfully overcome decades of established practices, entrenched behaviors, and the industry's traditional resistance to adopt new ideas and practices originating from outside the world of construction. In the United Kingdom, the T5 project became a change program of industrywide scale.

Project Operation Phase

The opening of T5 marked a milestone in British aviation history. Queen Elizabeth II and key government officials attended the opening ceremony for T5, and the media praised the achievement of building this terminal. However, when BA began to transfer its services to T5, a fiasco caused by a failed luggage-processing system captured more public attention.

It was reported that BA had clogged up about 28,000 bags, cancelled 500 flights, delayed its full operation of T5, and had losses of at least £16 million. In a written report produced by the Transport Committee, information technology (IT) failure and insufficient testing were identified as the major causes of the chaos. BA's chief executive, Willie Walsh, reeled off a list of failures. Staff had not been trained properly, they were unable to park when the car parks became too full on the day of opening, staff security searches were delayed, and construction work on parts of the building was not finished when the airport opened. Out of 175 lifts, 28 were not working; 17 are still broken, with 11 still to be fixed by the end of May.

BA's written evidence showed how many IT problems staff had to contend with. To begin with, loading staff could not sign onto the baggage-reconciliation system. They had to reconcile bags manually, which caused flight delays. Problems with the wireless LAN (local area network) at some check-in stands meant that staff could not enter information on bags into the system with their handheld devices. During testing on the baggage system, technicians installed software filters in the baggage system to prevent specimen messages generated by the baggage

system during the tests from being delivered to the “live” systems elsewhere in Heathrow. But the filters were accidentally left in place after the terminal opened. As a result, the T5 system did not receive information about bags transferring to BA from other airlines. The unrecognized bags were automatically sent for manual sorting in the terminal’s storage facility. Despite the rocky start of T5 in the first month, the new terminal has served its purposes well ever since.

Observations of the Researcher

By interviewing Patrick Godfrey and summarizing existing literatures, government reports, and media coverage, the researcher has observed the following:

- It is possible and necessary for the management team of complex projects to learn from previous experience as well as from other sources, even from other industries. The T5 team has learned from the early accidents occurring during the construction of the Heathrow Express project and, as a result, has changed its approach toward project risk management. Further, the T5 team has employed management methods that are rarely applied in the construction industry, such as just-in-time manufacturing, to enhance the productivity of construction sites. All of this experience and knowledge helped the T5 project meet the criteria of time, quality, cost, and safety.
- Leadership and organization design are crucial for the success of a complex project. The planning and design phases of a complex project are perhaps the most challenging and turbulent periods. Potential changes and new trends in technology, requirements, and all other aspects challenge the project team. Without consistent and capable leadership, this phase could cause immense problems in the future. Furthermore, such a complex project as T5 involves multiple parties that include contractors, clients, and other stakeholders,

and in most cases, different parties have conflicting interests. How to deal with this delicately is a challenge to all senior managers. T5's success in this area is that it has a top management team comprised of senior staff from BAA, BA, and other organizations to tackle problems promptly.

- As almost every complex project is to some extent nonreplicable, the experience learned from one site cannot fully be transplanted to another without integrating new considerations. T5, in this respect, is successful because innovation has been embraced. Technically, the design of T5 includes many technology breakthroughs, such as the terminal building, its transportation infrastructure, and its environmental protection. One notable management aspect is that the T5 project management aspired to “thinking differently” and adopted many innovative approaches. Lessons from other industries helped the management team members to broaden their views and hence stress the complexity in the T5 project properly.
- During the construction process of the T5 project, risks were well managed. A new thinking about risk management was developed by the project team. The team found that transferring risks to contractors does not reduce the overall level of risk as ultimately it is the project that will suffer. By considering this, the team has endeavored to reduce the risk in design and project execution and to resort to external bodies to share risks.

Also, the chaos of T5's inauguration gives precious lessons on how a complex project can go wrong in its delivery stage. Although various sources have identified the reasons for failures—such as IT failures, insufficient testing, lack of training, incomplete design, and so forth—two formal theories can be referred to showing that all problems can be linked to complexity.

- According to Perrow (1), accidents are inevitable in complex tightly coupled systems. The complexity means that unexpected interactions occur between independent failures in a system. The tight coupling means that these interactions can escalate rapidly and cause a system breakdown. It is the combination of complexity and tight coupling that makes such breakdowns inevitable, and so Perrow refers to such occurrences as "normal accidents" or "systems accidents." Systems accidents involve the unexpected or unanticipated interaction of multiple failures in a complex system. The complexity may be technological, organizational, or both.
- The high reliability theory suggests that the effects of tight coupling and complexity can be overcome by the use of a variety of organizational design and management strategies that counter the effects. Such strategies include making safety the main organizational objective; decentralizing decision making to allow for prompt and flexible responses to unforeseen events; creating a culture of reliability that enhances safety by encouraging uniform and appropriate responses by field-level operatives; performing continuous operations, training, and simulation to help create and maintain high reliability operations; and practicing trial and error learning from accidents or near accidents both within the organization and externally

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Bergen Light Rail, New Jersey

Introduction

The Hudson-Bergen Light Rail Transit System (HBLRTS) is a 20.3-mile-long light rail project that connects the densely populated New Jersey's Hudson River waterfront communities. The project also supports significant economic development that continues to take place in the region. The HBLRTS was built in three minimum operable segments (MOS). MOS2 (the subject of this case study) is a 6.1-mile-long system extending from Hoboken to Tonnelle Avenue Park-and-Ride facility in North Bergen and an extension between 22nd Street and 34th Street in Bayonne, as shown in Figure B.6.



Figure B.6. MOS2 system map (August 2004).

MOS2 features a major tunnel (the Weehawken tunnel with a length of 4,100 ft), which includes the new Bergenline station at a depth of 160 ft from the surface. MOS2 limits are identified on the map in Figure B.6.

The HBLRTS started as a traditional design-bid-build (DBB) project. In 1994, it was determined that by using the traditional approach, the first operating segment would not be in service until 2005 because of funding constraints and other considerations. Because of these concerns, NJ Transit decided to use the design, build, operate, maintain (DBOM) approach for project delivery (1). Using this approach, NJ Transit was able to deliver the MOS1 3 years earlier than if it had used DBB. For MOS2, NJ Transit decided to retain the services of the DBOM contractor of the first segment, the 21st Century Rail Corporation (a subsidiary of Washington Group International). The MOS2 DBOM contract was negotiated as a large change order to the MOS1.

Project Planning and Procurement Phase

Cost

The original total awarded value of the MOS2 contract was \$554 million, and the final total cost was \$611 million. The total cost for MOS2 was estimated at \$1.2 billion, with the rest of the cost being real estate acquisition and soft costs. Though the project's cost, estimated with the help of a contractor, was not a major issue in this project, it took more than a year to arrive at a mutually acceptable price. Because of the lengthy negotiation process, NJ Transit went to bid civil works in MOS3. As regarding contingency, the project had both allocated and unallocated contingency, and different contingency levels were used for various tasks. For example, the contingency rate used for utilities was higher.

Schedule

The DBOM approach was used to deliver the project as quickly as possible. DBOM was successful in cutting the duration of MOS1 by more than 3 years. The same planning effort that was used for MOS1 was continued for MOS2 as well. The owner opted to give control of the design to the contractor in order to accelerate construction. However, the owner set milestones that were not affected by third parties and held the contractor accountable for those milestones. Also, DBOM and contract provisions made the contractor solely responsible for milestones and the final deadline.

Technical

As the first public transit project in the nation to use the DBOM construction methodology, NJ Transit was awarded the American Public Transportation Association's prestigious Innovation Award for use of the DBOM methodology in September 2000 (1). The DBOM contractor was the 21st Century Rail Corporation [URS Washington Division (70%), Itochu Rail Car and Kinkisharo USA (30%)], chosen from two responsive bidders out of five bidders in total for MOS1. The owner required bidders to submit technical proposals for MOS1. These proposals were reviewed and commented upon. On the basis of the owner's feedback, the bidders submitted their final technical proposals, which were ranked by the owner for different areas (such as stations, tracks). The bidders also submitted a separate sealed price. The evaluation was based on 40% price + 60% technical score. MOS2 was a change order attached to MOS1. The owner negotiated the price for the MOS2. According to the interviewee, the negotiation process took much longer than anticipated (more than a year) and was deemed ineffective. Because of this, in MOS3 (a much smaller project of under \$100 million) the civil work was put to bid.

NJ Transit set up a separate division to implement the HBLRTS project with high priority. Use of DBOM allowed the contractor to integrate design and construction more effectively. Also, the integration of civil and systems work, which is a major issue in transit construction, was accomplished effectively because of the nature of the delivery method. The contractor had the ability to optimize project quality against expenditures. Contractors could spend more on construction and less on later maintenance or vice versa. However, the owner specified minimum levels of acceptable construction quality in the contract. According to the interviewee, the DBOM contractor opted to spend more on capital costs to minimize the cost of upkeep.

Context

The MOS2 alignment goes through several communities in one of the most densely populated parts of New Jersey. A multitude of parties were involved because of the project size and the length of track. These characteristics created formidable challenges for the project. Governor Christine Todd Whitman brought in a new transportation commissioner, Frank J. Wilson, to help jump start this effort. A separate office was established in NJ Transit to manage the HBLRTS project. The project was highly popular, according to the interviewee, and this helped in getting public acceptance. The project team had dialogues with communities and kept in touch with the local residents. NJ Transit and the contractor both had staff for community outreach and conducted as-needed meetings with the community.

The land acquisition activity caused an increase in property values even after the deadline for appraisals had passed. Higher property values caused an increase in the needed acquisition funds, and the project had to go to the board of directors of NJ Transit to get approval for higher prices, which caused delay and increased the cost. To manage the land acquisition more

effectively, the property acquisition software PAECE TRAK was used. This is a custom-built software developed for NJ Transit that allows the owner to upload parcel maps, appraisals, counter appraisals, track the history, and so on.

Successful utility relocation had a major impact on the project schedule. Because of the unique nature of the DBOM concept, it was decided to complete the utility design to the 80% to 90% level (2). The project required a minimum of 30% participation by disadvantaged business enterprises (DBE) during design. Several DBE subconsultants were hired to work on mapping and locating existing utilities and designing the utility relocation work.

Coordination with the railroad company operating the freight line was another major issue. The freight company was using the ROW during the early stages of construction, so some temporary accommodation was required by the project, and that was well handled.

Financing

The project was mainly funded by the Federal Transit Administration (FTA) and the State of New Jersey. According to NJ Transit (1), 61% of the cost of MOS1 and 41% of the cost of MOS2 were funded by FTA. The Full Funding Grant Agreement (FFGA) pays according to a multiyear schedule, but the money was needed in a shorter construction period, which meant that more money was needed upfront. Issuing Grant Anticipation Notes allowed issuing of bonds with FFGA as collateral. Also, New Jersey's Economic Development Authority bonds and Certificate of Participations (COPS) bonds were issued, with COPS being used for purchase of vehicles and related consultants.

Project Execution and Operation Phase

Cost

There was no retainage clause in the contract; the contractor gave back \$250,000 in lieu of the owner retaining part of its payments. The lack of a retainage clause caused no problem in this project. The DBOM approach helped to limit scope creep, which is usually caused by stakeholders' demands or counterdemands. The DBOM delivery pushed through the myriad of permits and community meetings swiftly, according to the interviewee. During the operations phase, the contractor/concessionaire is paid on the basis of actual car-miles, and the money comes only from state funds, which are scarcer compared with federal funding that was available during construction. As a result, NJ Transit had to work on the pattern of scheduling and routes to minimize costs for running the system.

Schedule

Contract provisions made the contractor responsible for meeting milestones and final deadline. However, the owner still had its own schedule control and scheduling system/software. There were monthly schedule meetings. The contractor's work was physically checked and measured against schedule, and payments were tied to actual project progress. A firm was hired to implement schedule control, which was very effective. Scheduling software (P3 in this case) helped with an effective schedule control on the project.

Technical

MOS2 was negotiated as a large change order of MOS1, and the DBOM delivery method allowed the contractor to integrate design and construction, which accelerated the delivery. The

DBOM contract requires the contractor to operate the system for 20 years. This, in effect, allowed the contractor to optimize the project cost with quality of work because that would affect the cost of maintenance.

There were several change orders for differing site conditions and utility relocation, but nothing extraordinary was noted during the interview, with the exception of a large claim by the contractor (\$116 million) for the tunnel work, which still remains unresolved. The owner did not use the Dispute Resolution Board in this project. The contract did not have a liquidated damages clause, but the owner could go after actual damages.

Context

Utility coordination and public emergency services were considered to be important factors during the construction phase. Since the project was done in densely populated areas, utility coordination could have been a problem. It was decided that all water, sanitary, and storm sewer construction would be done by the DBOM contractor and that all other utility construction would be done by the respective utility agencies. Specialty contractors were hired to handle all utility relocation at each intersection and coordinate with the utility companies involved. According to the program manager, completing the utility relocation design up to 90% helped this risky activity to flow smoothly (2).

Because of the length of the project and the tunnel, a safety certification process was carried out in which project staff met with town officials and police to explain emergency issues. There were emergency drills for fire or rescue (smoke test in tunnel) as well.

Financing Plans

No specific issue was noted for this section.

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I-95/New Haven Harbor Crossing

Introduction

The I-95/New Haven Harbor Crossing (NHHC) Corridor Improvement Program is a multimodal transportation program that features public transit enhancements and roadway improvements

along 7.2 miles of I-95 between Exit 46 (Sargent Drive) in New Haven and Exit 54 (Cedar Street) in Branford. The objective of the program is to improve traffic conditions along I-95 in Greater New Haven, Connecticut. The program owner is the Connecticut DOT (ConnDOT). One of the main components of the program is the new Pearl Harbor Memorial Bridge that is the nation's first extradosed bridge. The program is complex because it features many scheduling-, technical-, and context-related challenges encompassing transit and highway work.

Project Planning and Procurement Phase

Action Taken	Date
Draft Environmental Impact Statement (EIS) initiated	1992
Final EIS	March 1999
FHWA Record of Decision (ROD)	August 1999
Request for bids	May 2006
No bids received on bid day	December 27, 2006
Restructured design into smaller work packages	
Construction starts	2000
Construction complete	Estimated 2016

Constructed in the late 1950s, this stretch of roadway is part of the heavily traveled northeast corridor between New York and Boston. It is situated in a densely developed urban area with a mixture of commercial, industrial, municipal, and residential development. I-95 currently accommodates traffic volumes in excess of 140,000 vehicles per day in this area, more than three times the 40,000 vehicles per day planned for in the original design.

The main goals for the program include

- Improving traffic congestion and preventing it from continuing during the off-peak hours, and
- Remedyng the structural deficiencies of the existing I-95 bridge (Q-Bridge) over New Haven Harbor.

ConnDOT and FHWA have worked closely with the South Central Regional Council of Governments and other federal and local agencies to develop an acceptable strategy to address transit and transportation needs in the corridor.

The program will replace the existing I-95 crossing over New Haven Harbor (locally known as the Q-Bridge) with a new signature structure, the new 10-lane Pearl Harbor Memorial Bridge. This major bridge will be the nation's first extradosed bridge.

The program also contains transit enhancements that include a new Shore Line East commuter rail station at State Street in New Haven. Throughout the reconstructed corridor an architectural theme, featuring coordinated color and design elements, has been incorporated into the designs (<http://www.i95newhaven.com/>).

The study period for the project spanned almost 10 years during the 1990s and culminated with the FHWA's approval of the Record of Decision in August 1999. Parson

Brinckerhoff is the program manager for the project, and the design of various contract packages is performed by section designers whose efforts are coordinated by the program manager. For design effort, the project has had 12 contracts with 5 different design firms. For construction, the project also has had 12 contracts, with 8 different contractors involved (some of the contracts are now long completed). For consultant and inspector services, the project has had 12 contracts with 3 consultant or inspection firms.

The original program contract has gone through several changes and repackaging to cope with scheduling and context-related challenges facing the project. The program is scheduled for completion in 2016. Currently, the largest effort is the construction of the new bridge over the New Haven Harbor.

Cost

According to the FHWA website, the initial finance plan estimated the baseline cost as \$0.834 billion in December 2000. Currently, the project is estimated to cost \$1.94 billion, which is roughly 2.3 times the original baseline value. The main cost drivers, according to project personnel, have been the delays caused during the lengthy project development, issues with stakeholders (examples include the Yale Boathouse and the Fitch Foundry) that caused major delays, the no bid on the new bridge project, and the effect of inflation, especially during the 2005–2007 period when material and labor costs increased substantially. Recently, construction prices have stabilized.

Schedule

Schedule has been the main challenge in the I-95 NHHC program. In fact, the project team that was interviewed ranked the schedule dimension ahead of the other four dimensions (cost, technical, context, and financial). Many factors have contributed to this issue. The project size and the fact that it consists of several major construction packages including transit and highway, the timing of project financing appropriations that dictated what could be constructed at any given period, the number of entities involved, and the difficulty in scheduling activities around a busy and active artery in a densely populated area all contributed to the scheduling challenges. A major complexity issue was the interdependence of projects. The delay in the completion of one project could affect the start time of other projects.

Several issues had impact on the project, which almost caused FHWA to pull funds from the project. The Yale Boathouse relocation issue, the Fitch Foundry, the Long Wharf, and West Haven expansion efforts described under “context” were all factors that caused major delays and increased program costs. Another major factor for the delay was the no-bid situation for the Q-Bridge that was explained under “technical.” ROW acquisition had a negative effect on project schedule as described under “context.” As can be observed, many of these factors that the project personnel perceive as *schedule* factors can be classified as *technical* and *context* factors in R10 research project terminology. The main reason is that while these are context and technical factors, they adversely affect project schedule the most. A current milestone schedule as of April 2010 is shown in Table B.1.

Table B.1. Current Milestone Schedule

Contract	Now (April 2010)

		Early Start	Early Finish
Completed	A	October 16, 2000	June 6, 2002
	C1	September 23, 2003	August 11, 2006
	C2	September 26, 2005	October 6, 2008
	D	June 28, 2002	July 26, 2004
	D1	February 1, 2008	November 3, 2008
	E1	November 12 2004	January 8, 2007
	GNHWPCA	December 10, 2007	April 22, 2009
Current	B	November 27, 2009	June 30, 2015
	B1	April 28, 2008	August 4, 2011

	E2	October 22, 2008	November 16, 2011
Adjacent	Howard Avenue	-	-
Future	E	March 12, 2011	March 11, 2014

Technical

The Pearl Harbor Memorial Bridge is the first extradosed bridge in the nation and as such could add to the complexity of the project from a technical point of view. The extradosed system is a hybrid design that is a combination of a box girder bridge and a cable-stayed bridge so as to expand the span of the box girder. Extradosed bridges have been successfully designed and constructed for several years in both Europe and Japan. The extradosed main spans of the new Pearl Harbor Memorial Bridge were designed in both steel and concrete, which allowed bidders to choose the least-cost alternative. The bridge contract was the largest and most-complex package. The new bridge project received no bids by the deadline of December 27, 2006, after being put on bid in May 2006. As a result, ConnDOT divided the project into multiple contracts, which led to an increased time requirement for finishing the project. The repackaging of the bridge caused significant delays and cost increases. The project personnel interviewed thought that the reason for no bids was that the bid package was too large and complex for the contracting community (especially local contractors and those with prior ConnDOT experience) and was deemed extremely risky by potential bidders.

Another technical issue was the presence of contaminated soil and water on the program site. This increased project cost caused delays in obtaining the required permits for processing of contaminated material.

Value engineering workshops at the conceptual engineering phase and at the end of preliminary engineering were conducted by the program manager. Also, structured value engineering from contractors was solicited, and constructability reviews were required from section designers.

Context

The project location in a highly urban area, the necessity to keep the roads open during the construction phase, and the magnitude of the program all contributed to complexity. Although during the long planning process (about 10 years) many of the contextual issues had been studied and resolved, many context factors still affected the project's schedule and budget during design and construction. The program affected several municipalities, and the owner and program manager had to conduct numerous coordinating meetings to ensure that information was reaching the right people at the right time.

Land acquisition also posed some challenges and took longer and cost more than anticipated. As an example, the taking of an elementary school delayed the project because the project was affected by the school schedule.

Politics had a major impact on the project and its evolution, as can be expected in such a program. As significant examples, two historical structures—the former Yale Boathouse and the Fitch Foundry—were in the way of the original planned path of the new bridge. Also, New

Haven Mayor John DeStefano Jr. demanded that the expansion of I-95, which includes Long Wharf and the West Haven area, should be included in the plan as well.

Later, it was decided to salvage significant architectural elements from both buildings to deliver to the City of New Haven for adaptive use and/or public education purposes. Meanwhile, environmental studies and design work continued on the Long Wharf and West Haven areas and eventually affected the program schedule and budget.

Utility coordination was another complex issue facing the project. The total cost of utility relocation is estimated at \$85 million. All kinds of utility lines lie in a crowded corridor, and major coordination with multiple agencies and corporations was needed to plan and execute relocations.

Financing

The project is mainly funded by FHWA, which is covering about 88% of the total cost. The rest is covered by state and local funds. FHWA requires a project financial plan that the grantee has provided. Each of the projects is scheduled according to availability and the cash flow distribution of the federal assistance for the project. This constraint has caused ConnDOT to rearrange and package projects in a manner that is compatible with availability of federal funds rather than with other constraints such as expediency.

Project Execution Phase

The execution phase started in 2000 with the construction of State Street Station, a new commuter rail station for Shore Line East's service between New Haven and New London. Much of the work involving widening and reconstruction of I-95 and Frontage roads in East Haven is now complete. Major construction effort is now concentrated on the new Q-Bridge,

bridge foundations and flyover (Contracts B, B1, and E2), and the I-95/I-91/Route 34 Interchange (Contract E, yet to be let) south of the bridge. The project is currently scheduled for completion in 2016.

Cost

The length of project development coupled with issues stemming from land acquisition and the no-bid situation with the Q-Bridge contract caused major cost overruns in the project budget. Another issue was the inflation in the mid-2000s that caused a major increase in the bid values. The owner tried to reduce the risk of material cost issues by producing a formula-based method that enabled the contractor to submit a bid price based on fuel price. On the basis of the actual fuel price, the bid price would be adjusted. The same approach was used for cement and asphalt. For coping with volatility in steel prices, the owner asked the bidders to omit the cost of raw steel when bidding. This way, more contractors were incentivized to bid on the projects without having to incorporate large contingencies. The prices of these materials have since stabilized but were of great concern a few years ago.

Schedule

To keep the program on schedule, the program manager (PM) developed a work breakdown structure (WBS) for the project. Contractors were required to develop their schedules according to the WBS. The scheduling system is implemented by using the P6 software system. The PM runs coordination meetings every 2 weeks to ensure that each issue is pursued and resolved. Furthermore, an earned value (EV) system was developed for the project, and an analysis is conducted every 3 months to assess project status with respect to budget and schedule. This analysis also produces a 3-month look-ahead schedule for the program.

The NHHC consists of several contracts. These contracts are interdependent, and delay in one can cause delay in the start time of other contracts. Because of this, the owner included early-completion incentives in contract documents to ensure that projects are completed on time.

Technical

Because of the size and complexity of the NHHC, ConnDOT created a District 3A office that is dedicated to this program. To effectively deal with potential disputes during the construction phase, the owner implemented a partnering program. Although the contracts include binding arbitration, it is preferred that disputes not reach that point. A Contract Board of Review is available to address disputes. Mediation is voluntary (if both parties agree to it). The owner perceives its approach to dispute resolution as an effective and proactive approach.

Contaminated soil and water were encountered. Much of the ROW is located in industrial areas, and the level of contamination varied in the soil and groundwater. The contracts make the CSM (contractor soil manager) responsible for handling contaminated material. All contaminated soil and water is stored in predetermined locations. These materials are then either reused (if allowed) or disposed off site.

Context

Several context issues have already been discussed. One of the major issues was the no-bid situation for the Q-Bridge contract. The owner decided to do a contractor outreach to ensure that a new repackaged bid announcement was better designed and received by the contractor community. This effort bore fruit, and the contractors' feedback resulted in a new work packaging that received competitive bids.

Another major issue was the coordination of utility relocation. The total utility relocation in various contracts adds up to \$85 million. The PM took an active role in this respect by identifying conflicts, setting up meetings with utility companies, coordinating their work, and keeping them accountable. Although the contracts called for contractors to be responsible for the coordination effort, the PM and owner did the coordination work because of the sensitivity of the activities.

Another major issue was railroad coordination. The PM took the main responsibility. Protective services and coordination of power outages with AMTRAK were the main tools of this effort.

Financing

No specific issue was noted for this section.

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Oklahoma City I-40 Crosstown

Introduction

The I-40 Crosstown project in Oklahoma City, Oklahoma, consists of building 4 1/2 miles of new Interstate in an existing railway corridor to replace the existing elevated Interstate just north of the project site (1). This report will detail the processes used to make decisions during the project's planning and procurement, execution, and operations phases.

Project Planning and Procurement Phase

Action Taken	Date
Notice of Intent and Environmental Impact Statement	March 1995
Preliminary engineering begins	July 2001
Final Environmental Impact Study	January 2002
Record of Decision	May 2002
ROW purchasing complete	March 2003
Design contracts awarded	June 2003
Utility relocations complete	June 2005
Construction under way	November 2005

Cost

The original cost for the project was \$320 million in 1995 dollars (5). Today that equates to \$600 million (2). In every reevaluation that has been conducted by the Oklahoma DOT (ODOT) and FHWA, the original estimates are very close to what actual construction has cost (2). ODOT set aside some contingency for a few unknown site conditions in the corridor, which has been used. For about a year inflation was completely unpredictable from day to day, but there were provisions for those unforeseen factors in the original estimate (2).

Schedule

The original schedule for completion of the project was to be complete and open to traffic on September 15, 2008, at 10:00 a.m. (1). This was of course if the financing were available from the federal government (2). The project was scheduled originally to be able to meet that deadline (2). Now it is scheduled according to how much money is allocated (2). This determines which work packages can be completed, when they can start, and how long it is expected to take to complete (2). The new completion date is not as specific, but the new Crosstown is planned to be open to traffic in 2012 (1).

Technical

The planning phase for the engineering and design of the project was managed somewhat like a design-build project (2). MacArthur and Associates Consultants were contracted for the initial planning and research phase. They were then contracted to become the project managers for the project, because ODOT did not want to lose all of the knowledge and experience this firm had

gained on the project during the execution phase (2). ODOT put out a Request for Proposal for the detailed design after the Record of Decision was signed for Alternative D (2). Because of the size and complexity of the project, ODOT decided to break up the project and choose multiple designers (2). Figure B.7 shows a graphic representation of how the project was split up.

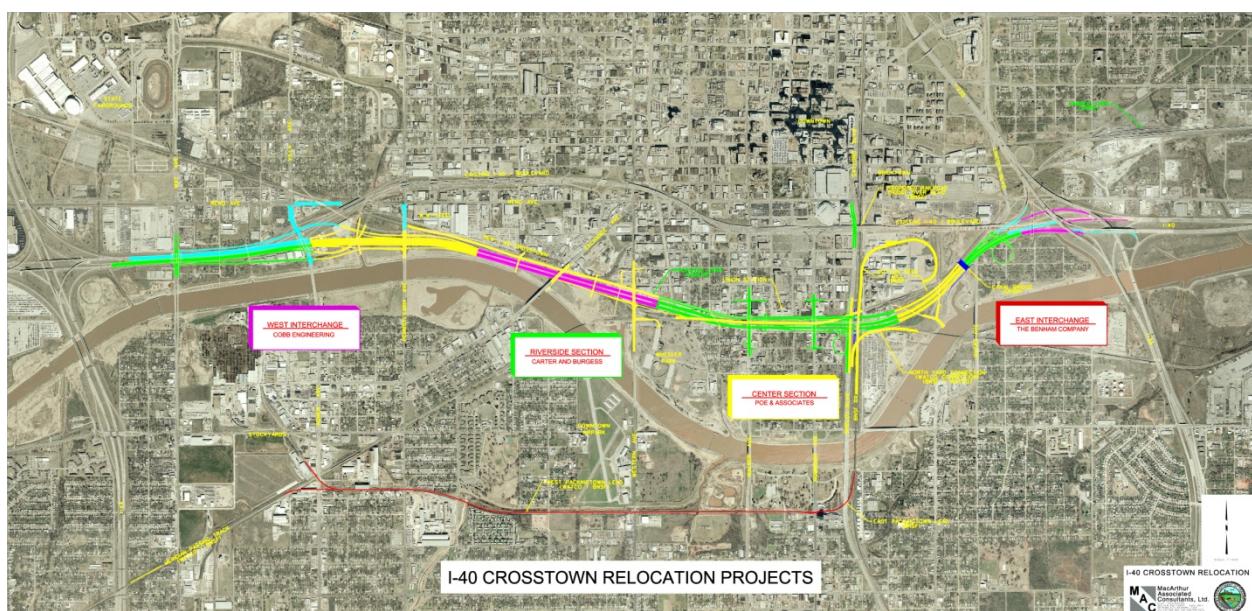


Figure B.7. I-40 Crosstown design responsibilities.

ODOT also chose to do this because of the time frame; the DOT did not believe that just one firm had the experience and manpower to complete the design in the time frame they were looking at to start construction (2).

Context

The context issues that ODOT primarily focused on in this project were noise and vibration, ROW acquisition and relocation, public opinion, and procurement restraints (4).

Noise and Vibration

The issue related to noise and vibration contributed heavily to items included in the design for the new I-40 Crosstown. Because the new I-40 is located directly adjacent to the Riverside Neighborhood, future traffic noise levels were estimated to exceed that of FHWA noise abatement criteria (4). Noise barrier walls were deemed feasible to mitigate the noise levels for the residential areas along the Alternate D route (4). Also, because of public concern about vibration, ODOT has committed to perform structural surveys before and after construction is completed for several buildings along the Alternate D route. Previous studies did not reveal any risk due to vibration for these buildings (4).

ROW and Relocation Issues

All of the build alternatives for the new I-40 were going to affect minority and low-income persons, who are more highly concentrated in the I-40 corridor than in the city as a whole (4). The selected route, Alternate D, had a greater impact on the relocation of minority and low-income residences and a lesser impact on minority and low-income businesses than did the other build alternatives (4). The higher residence relocation was because of a linear park adjacent to I-40 that is to be built as a buffer between the Riverside Neighborhood and the new alignment of I-40, which also includes a landscaped pedestrian bridge over I-40, shown in Figure B.8 (4).



Figure B.8. Schematic pedestrian bridge design.

Because this is a public project and is being built in an existing railroad corridor, the relationships with the railroads were extremely important. ODOT worked extensively with the Burlington Northern Santa Fe Railroad and the Union Pacific Railroad throughout the planning phase of the project to reach a solution that was acceptable to all parties (2). In the interview with John Bowman, the project development engineer over the project, he stated that it was his belief that the positive relationship that ODOT maintains with the railroads is the reason that everything has gone relatively smoothly.

Public Relations

Public relations, including that of various state and city organizations, were also very important to ODOT in the planning stage. There was a notable amount of effort on the part of ODOT to ensure that the residents and leaders of Oklahoma City were involved in the process to create the most suitable solution for the project (2). The planning process from inception to completion took a total of 10 years (3). Sixty-four written and oral comments were received on the Draft Environmental Impact Statement, which was considered extremely low for a large project such

as this (2). The low return was attributed to the efforts made at the beginning of the project to include the public. The DOT has continued to keep the public informed while the Crosstown project is still under way and has dedicated a website to keeping the public up to date (www.40forward.com). Project photographs, a timeline, and general information can be found there (1).

Procurement Restraints

During the planning phase, ODOT realized that completing the Crosstown as one project would be a major undertaking. The DOT wanted to use local design and construction firms but recognized that the local resources would not be able to handle such a large project (2). Also, because the project was to be funded primarily by federal dollars, ODOT knew that it would take a very large allocation of funding to complete the project and that this funding would be unlikely (2). For these reasons, ODOT split the project into work packages so that local Oklahoma firms would be able to realistically compete for the projects and that funding could be realistically applied to the smaller projects (2).

Financing

As mentioned earlier, this is a public project financed by federal dollars (1). ODOT did not know how much money would be allocated at any particular time, simply that it would be allocated (2). In the planning phase, funding for ROW acquisition and utilities relocation was allocated by FHWA (3).

Project Execution

The project is currently in the project execution phase. Of the 23 total work packages, 11 have been let to bid, 11 have started construction, eight have been completed, and three are still under construction (3).

Cost

The cost during the execution period of the project has gone through the major inflation of construction materials from 2004 to mid-2006 (2). ODOT continued doing cost checks against what was originally estimated, and while the materials were significantly higher, the inflation period evened out early in the project's construction phase. The current cost estimate to complete the project in 2012 is \$600 million (1). This includes higher than estimated costs of utility relocation and ROW acquisition and some site remediation that was unforeseen (2).

Schedule

The schedule for the construction during the execution period of the project has been driven by the financing of the project (2). Although the project team would like to transfer traffic from the current Crosstown as quickly as possible, work packages can only be let as the funding is available (2).

Technical

One of the key challenges during the execution phase of the project technically has been to ensure that the final designs have been completed for the bid lettings. Another challenge technically has been the sequencing of the work packages (2). This ties back into the financing issue; how much financing has been approved and is available drives which work package can be

let to bid (2). Figure B.9 shows a graphic representation of the timeline of the work package sequence.

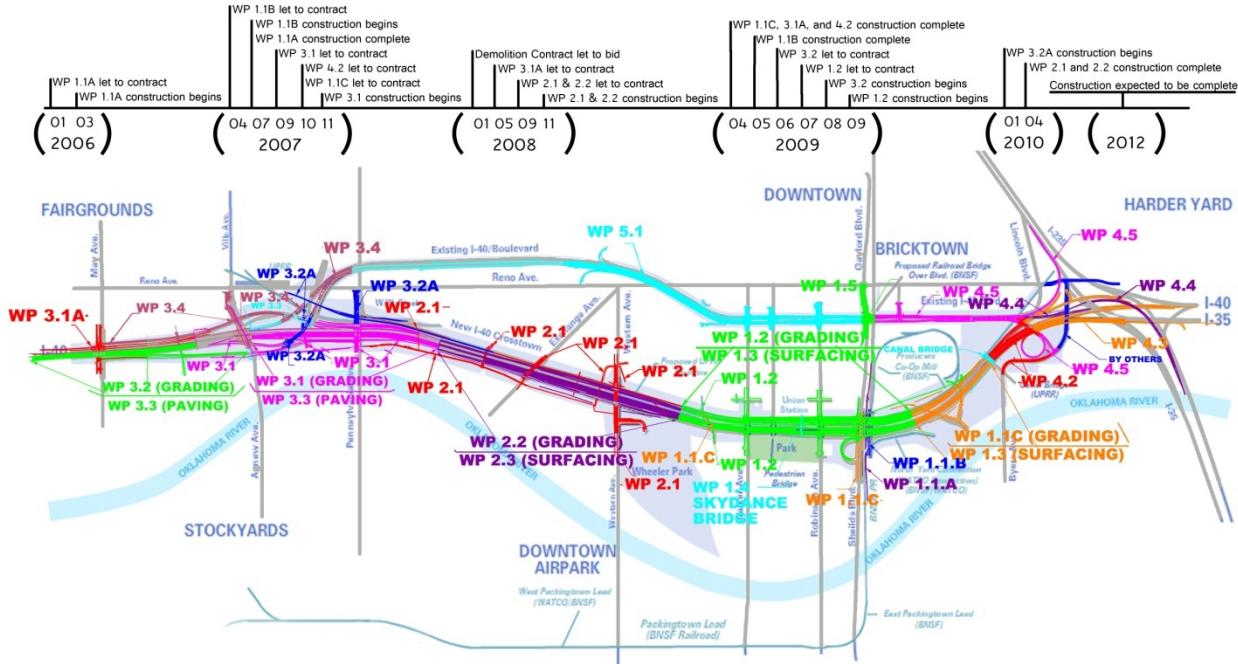


Figure B.9. Work packages and timeline.

Context

ODOT still views all of the context issues from the planning and procurement stage as viable issues (2). John Bowman still receives phone calls from concerned and curious citizens and coordinates with them over alternate routes to take when some of the city streets have been closed (2). This is one of the issues that the project team purposefully thought of when sequencing road closures (2). The citizen advisory committee still has meetings on the progress of the project, and the relationships made during the planning phase are kept alive and positive, whether they are with the public, railroads, or the leadership of Oklahoma City (2).

Financing

As discussed in the planning stage, financing is from the federal government and depends largely on what is approved per session in Congress (2). There are a lot of restrictions on how the money allocated can be used; for example, if the funds originated from a bridge building fund, that money can only be used for building bridges, not for site work or paving on a section of the project that is on grade level (2). The financing is one of the key reasons this project has been treated as complex (2).

Project Operation Phase

This project is 2 years away from this phase (1).

Conclusion

After meeting with ODOT project development engineer, John Bowman, it was concluded that this complex project has been so successful because of three major reasons. First, the DOT and FHWA spent a lot of time on the planning phase. Multiple public meetings, going out to present to various community groups, and trying to find the best solution for all parties involved contributed to the success of this project. ODOT used tools such as holding an Accelerated Construction Technology Transfer workshop to brainstorm ways to do the project better before construction started. The second reason the project has been successful is because everyone involved has gone about working on the project with the mindset of adapting to the daily happenings that can occur without warning. This ability to adapt to change has influenced the project's success. The final reason this project has been successful is that ODOT assigned a full-time project development engineer exclusively to the Crosstown project, which enabled him to concentrate on the success of this project and this project alone. These reasons have combined to

influence all of the different context, financing, technical, cost, and schedule issues of the project.

Observations of the Researcher

Greatest challenges

- Size of project and issues with design and construction for local industry,
- Funding, and
- Railroad relations.

Opportunities for success

- Nonadversarial relationships with the public and with the railroads,
- Everyone's best interests kept in mind,
- Project planning phase conducted extremely in depth,
- Many potential problems solved early,
- Project development engineer assigned exclusively to this project, and
- Single point of contact for public to voice concerns throughout planning and construction.

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Fort Lauderdale I-595 Corridor Roadway Improvements

Introduction

According to the Florida DOT (FDOT) Project Overview of July 7, 2010, the I-595 Corridor Roadway Improvements project consists of the reconstruction of the I-595 mainline and all associated improvements to frontage roads and ramps from the I-75/Sawgrass Expressway interchange to the I-595/I-95 interchange for a total project length along I-595 of approximately 10.5 miles and a design and construction cost of approximately \$1.2 billion. The project improvements will be implemented as part of a public–private partnership (PPP) with I-595 Express, LLC, a subsidiary created by ACS Infrastructure Development, which was awarded the contract to serve as the concessionaire to design, build, finance, operate, and maintain (DBFOM) the project for a 35-year term. The DBFOM project delivery was chosen as a result of initial findings that the project would take up to 20 years to complete if funded in the traditional way. FDOT found that if it could deliver the project by the DBFOM method, it could reap considerable cost savings over the life of the project as well as reach the traffic capacity 15 years sooner than it would have with traditional methods. The DOT will provide management oversight of the contract; will install, test, operate, and maintain all SunPass tolling equipment for the reversible express lanes; and will set the toll rates and retain the toll revenue. A project improvement map is shown in Figure B.10, and the project timeline is shown in Figure B.11. This report will detail the processes used to make decisions during the project's planning, procurement, execution, and operations phases.

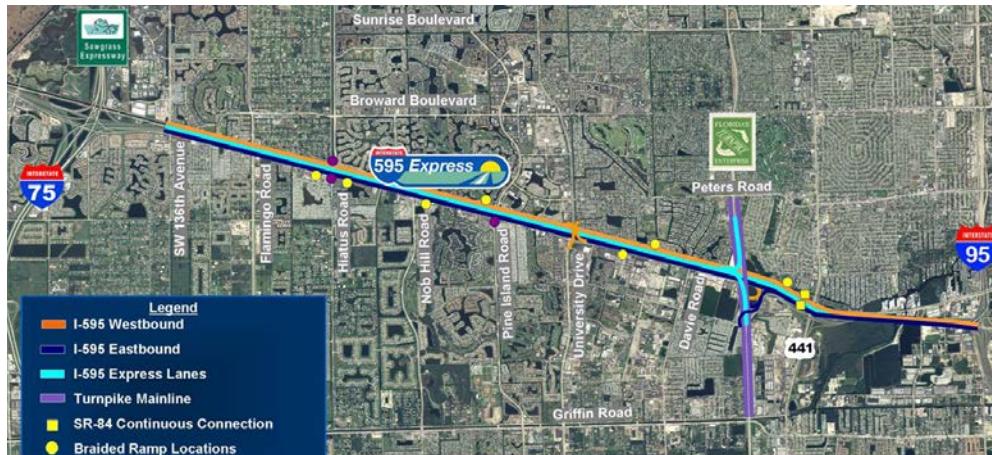


Figure B.10. Project improvement map (I).

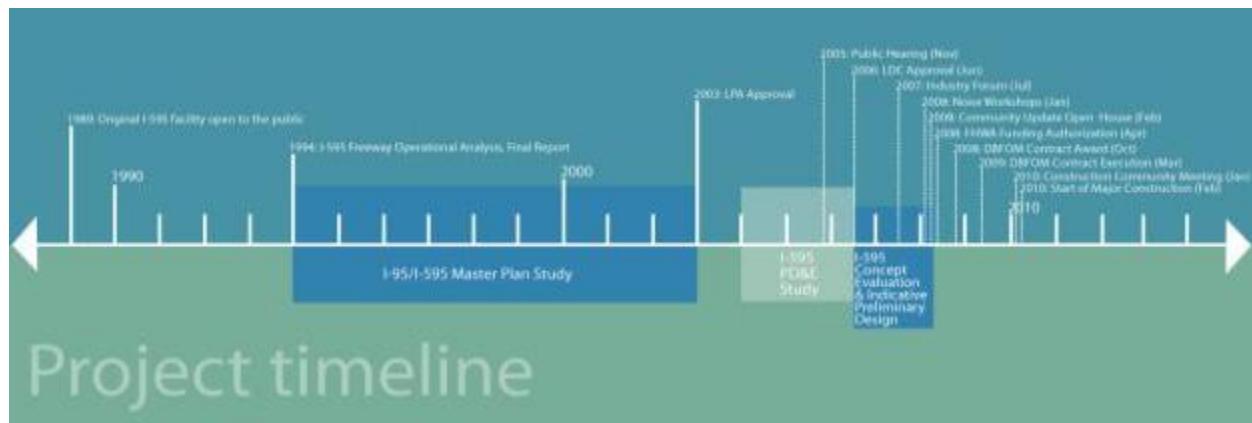


Figure B.11. I-595 project timeline (3).

Project Planning Phase

Action Taken	Date
I-595 corridor open to traffic	1989
I-95/I-595 Master Plan Study begins	1994

I-95/I-595 Master Plan Study completed	2003
I -595 Project Development and Environmental Study complete	June 29, 2006
Public workshops conducted	April–November 2005
Reynolds, Smith, and Hills, Inc. (RS&H) selected for corridor design consultant services	April 17, 2006
Notice to Proceed issued to RS&H	June 28, 2006
International Industry Forum	July 25, 2007

Cost

The initial cost for this project was estimated at \$1.5 billion. The cost factors that FDOT found to be more complex on this project in the planning phase were contingency usage, risk analysis, estimate formation, owner resource allocation, cost control, incentive usage, and payment restrictions (4).

Contingency Usage

I-595 corridor improvements were scrutinized more than other projects in terms of how the contingency would be assigned. FDOT had not ever done a formal process to get a contingency amount from a cost risk analysis, which is how the contingency was figured in the early stages of the project (4).

Risk Analysis

A formal risk analysis process was conducted to determine where the risk would be in the project as well as which party would be responsible for the risk: FDOT or the concessionaire (4).

Estimate Formation

The estimate formation was more complex for this project in the planning stages because of how the work had to be split up initially to match with the available public funding (4). Because of the incredible cost and the long schedule, the project management team began looking at alternative project delivery systems (4).

Owner Resource Allocation

FDOT developed a work program with funding codes, which was a very detailed financial plan that tied back to a work program that has been redone every year (4).

Payment Restrictions

Early in the planning stage, FDOT's District 4 realized that because of the very large scope of this project, its traditional design-build delivery mechanism was going to take many years because it required the work to be broken up to match the available funding (5). For this reason, the DOT started looking at other project delivery methods that could solve this shortfall and deliver the project much more quickly (5).

Schedule

The initial schedule for the construction was to start in the fall of 2009 and to finish in the spring of 2014 (4). The schedule factors that FDOT found to be more complex on this project in the

planning phase were timeline requirements, risk analysis, milestones, schedule control, optimization's impact on schedule, and resource availability (4).

Optimization's Impact on Schedule

In the planning stage, FDOT found that by completing the project in a traditional way, it could take up to 20 years to deliver the project in full (4). By looking at delivering the project with a DBFOM contract, the construction would be complete in about 4 and 1/2 years, which would save the DOT considerable money as well as complete the project 15 years earlier (4).

Technical

The technical factors that FDOT found to be more complex on this project in the planning phase were scope of the project, owner's internal structure, prequalification of bidders, warranties, disputes, delivery methods, contract formation, existing conditions, and technology usage (4).

Context

The context factors that FDOT found to be more complex on this project in the planning phase were public, political, owner, jurisdictions, maintaining capacity, work zone visualization, intermodal, marketing, local acceptance, and global and national economy (4).

Public and Political

During the planning stage, it was imperative to FDOT that the public be a part of the decision-making process. Many workshops, meetings, forums, hearings, and open houses were held specifically to gain input from citizens and elected officials for the project (3).

Jurisdictions

The I-595 corridor passes through or lies immediately adjacent to six governmental jurisdictions: the City of Sunrise, Town of Davie, City of Plantation, City of Fort Lauderdale, and Town of Dania, as well as unincorporated areas of Broward County (2).

Intermodal

Existing columns had to be designed around for future light rail construction (4).

Local Acceptance

This issue changed the original design of the express lanes in the center of the corridor. Originally, the express lanes were to be elevated above the at-grade I-595 (4). Members of the local community were opposed to the elevated lanes because they would be able to see the new lanes from their houses (4). Together with local citizens, FDOT redesigned the elevated portion to be at the same level as the rest of the lanes, and in the end, this has become a better solution for all parties concerned. The new design is much more economical and will not take as long to construct as an elevated version (4). Figure B.12 shows a typical section of the new design.

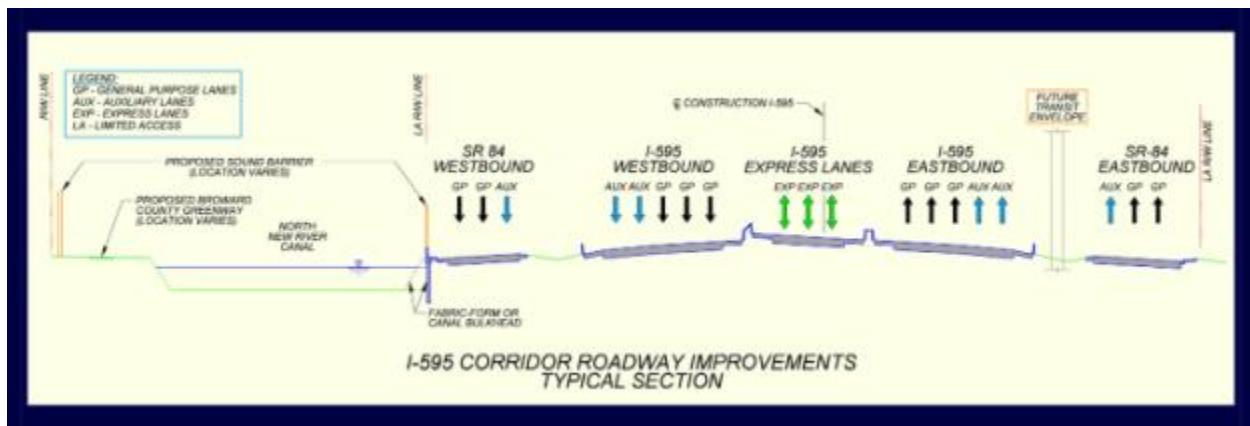


Figure B.12. I-595 typical section.

Financing

This is the first highway project in the United States to be delivered by the DBFOM method (4).

DBOM was attractive to FDOT primarily because the financing was available for the project and, as a result, speeded up the construction schedule (4). The financing factors that FDOT found to be more complex on this project in the planning phase were legislative process, project manager financial training, federal funding, advance construction, revenue generation, cordon and congestion pricing, PPP, global participation, and risk analysis (4).

Legislative Process

The legislative process that allowed this project to happen was the result of an agency initiative and was not project specific (4).

Project Manager Financial Training

Project managers were given “crash course” financial training from the financial advisors that FDOT partnered with to help with the financial side of the project (4).

Federal Funding

FDOT completed all steps needed to keep the project eligible for federal funding (4).

Procurement Phase

Action Taken	Date
FDOT issued Request for Qualifications	October 1, 2007
Statements of Qualifications received	November 5, 2007
Teams short-listed	December 3, 2007
Request for Proposal distribution	December 11, 2007
Technical and financial proposals received	September 5, 2008
Notice of Intent to Award Contract	October 24, 2008
Contract execution finalized	March 3, 2009

Cost

The cost factors that FDOT found to be more complex on this project in the procurement phase were contingency usage, risk analysis, estimate formation, owner resource allocation, cost control, incentive usage, and payment restrictions (4).

Cost Control

FDOT set up deductibles in the contract with the concessionaire, for instance, \$50,000 for small claims as well as hurricane deductibles (4). FDOT did this for items they saw as potential risks (4). FDOT also made the scope of work very clear in the contract documents so the addition of work would be less likely (4).

Payment Restrictions

The availability payments set up in the contract are to help make up the funding shortage by FDOT (4).

Schedule

The schedule factors that FDOT found to be more complex on this project in the procurement phase were timeline requirements, risk analysis, milestones, schedule control, optimization's impact on schedule, and resource availability (4).

Technical

The technical factors that FDOT found to be more complex on this project in the procurement phase were scope of the project, owner's internal structure, prequalification of bidders, warranties, disputes, contract formation, existing conditions, and technology usage (4).

Context

The context factors that FDOT found to be more complex on this project in the procurement phase were public, political, owner, jurisdictions, maintaining capacity, work zone visualization, intermodal, marketing, local acceptance, and global and national economy (4).

Public

FDOT continued to hold meetings and workshops to let the public know what was going on (3, 4).

Political

FDOT continued to hold meetings and workshops to let elected officials and local politicians know what was going on (3, 4).

Global and National Economics

One of the biggest challenges facing the project was achieving close of financing during the extremely difficult environment for obtaining debt in early 2009 (5). Difficulties in obtaining debt finance were resolved through the approval of TIFIA financing and bank loans provided by a group of 12 banks led primarily by Spanish banks (5).

Financing

The financing factors that FDOT found to be more complex on this project in the procurement phase were legislative process, project manager financial training, federal funding, advance construction, revenue generation, cordon and congestion pricing, PPP, global participation, and risk analysis (4).

Federal Funding

Because FDOT kept the project eligible for federal funding, it was able to receive a TIFIA loan (5).

Project Execution

As seen in Figure B.13, the concessionaire divided the corridor into nine work zones to manage the construction (2). These zones have been determined by major cross streets and do not include advance construction activities (2). Advance construction activities, initiated on June 15, 2009, include constructing the greenway along the North New River Canal, selecting interim ITS work,

selecting sound barrier wall construction, and relocating utilities (2). The concessionaire has designated two teams to manage the zones and will select contractors to perform the work in each zone per the requirements in the contract documents when “released for construction” plans have been produced (2). The construction operations will be monitored by the concessionaire in accordance with its approved Construction Quality Control Management Plan (2). There are eight interim milestones within the construction contract (2). Substantial completion should occur within 1,820 days from NTP 1, and final acceptance is to be 90 days after substantial completion (2). All construction is expected to be completed in the spring of 2014 (2).

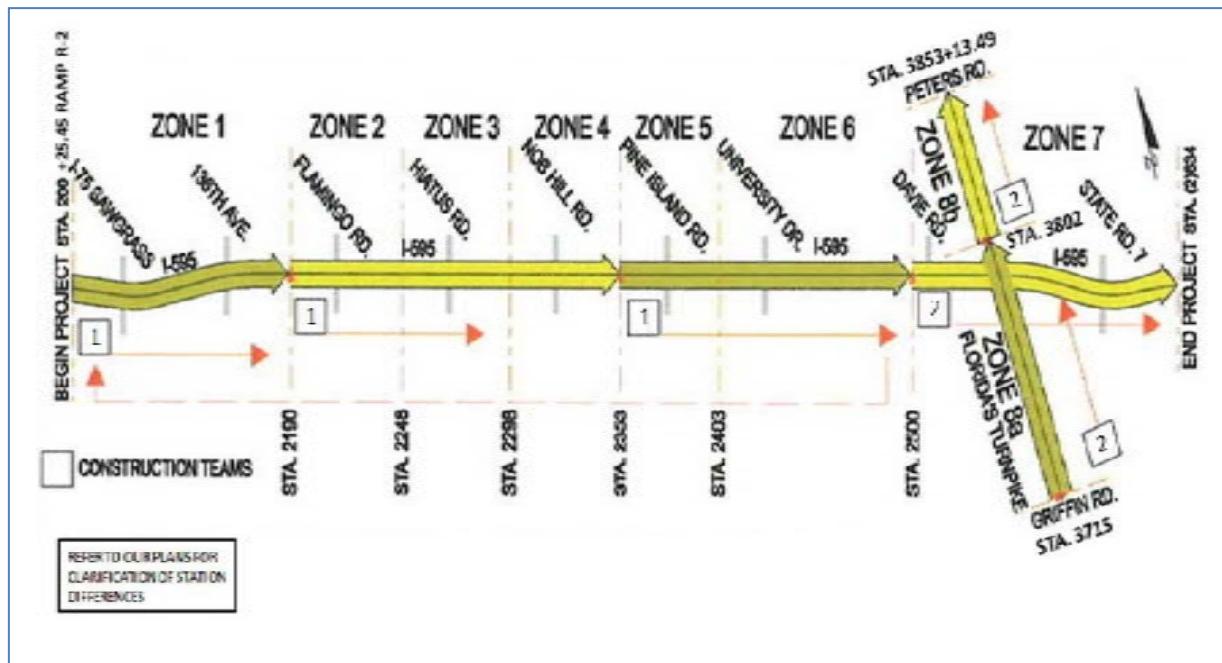


Figure B.13. I-595 work zones (2).

Cost

The cost at the time of the project award was \$1.835 billion (the cost factors that FDOT found to be more complex on this project in the execution phase were contingency usage, risk analysis, estimate formation, owner resource allocation, cost control, incentive usage, and payment restrictions (4)).

Schedule

The schedule factors that FDOT found to be more complex on this project in the execution phase were timeline requirements, risk analysis, milestones, schedule control, optimization's impact on schedule, and resource availability (4).

Milestones

As an incentive to complete the interim milestones during the course of the project, FDOT assigned milestone payments to be paid to the contractor if the milestone was completed in the time frame given (4).

Optimization

FDOT's goal during the construction period was to reduce its review period of submittals (4).

For instance, when the DOT received 180 upfront bridge submittals, it required more resources to review those submittals to reduce the amount of time it took to approve them (4).

- *Technical*
- The technical factors that FDOT found to be more complex on this project in the execution phase were scope of the project, owner's internal structure, warranties, disputes, existing conditions, and technology usage (4)

Scope of the Project

Reviews are conducted at intervals to make sure the concessionaire's plan meets FDOT specifications, and FDOT conducts audits of the concessionaire's personnel to ensure they are qualified (4).

Warranties

The warranties in place during the execution of the project are quite general and will become more specific the closer the project is to completion (4).

Disputes

The State of Florida Dispute Review Board is being used for this project and has proven very effective for previous projects (4).

Technology Usage

FDOT is using a variety of technologies during the execution phase of the project: ProLog, which was specifically purchased for this project for document control; smart boards at public meetings and workshops as well as for team meetings with the concessionaire; and hard tablets with cameras and the Global Positioning System (GPS) for site photos and information (4).

Context

The context factors that FDOT found to be more complex on this project in the execution phase were public, political, owner, jurisdictions, maintaining capacity, work zone visualization, intermodal, marketing, local acceptance, and global and national economy (4).

Work Zone Visualization

FDOT used 3-D animation and video on the project website (www.I-595.com) to show lane closures per day and also used dynamic message signs to give alerts to travelers on the corridor (4).

Marketing

During the execution phase, the project website provides the latest project information, and the job has also been branded with familiar logos from FDOT and the concessionaire, as shown in Figures B.14 and B.15 (4).



Figure B.14. FDOT's project logo.



Figure B.15. Concessionaire's project logo.

Local Acceptance

The concessionaire is using local contractors and materials as much as possible to help the local economy as well as to ensure continued local acceptance of the project (4). FDOT is using local businesses along I-595 for its events, such as catering from restaurants for business meetings,

conferences at local hotels, and any other function appropriate for local business (4). FDOT is also making it a priority to respond to all customers within 24 hours and putting tracking mechanisms in place to ensure that happens (4). Some additions to the construction were made specifically for local communities, such as the sound walls that are being constructed as part of the advance construction activities and the Broward County Greenway designed to encourage walking and biking along the new paths added along the existing canal that runs parallel to the corridor (4).

Financing

The financing factors that FDOT found to be more complex on this project in the execution phase were project manager financial training, federal funding, advance construction, revenue generation, cordon and congestion pricing, PPP, global participation, and risk analysis (4).

Project Operation Phase

The goal of the Corridor Management Team is to ensure that the I-595 mainline, SR-84, ramps, and the new express lanes system are managed, maintained, and operated in a manner that is consistent with and satisfactory to FDOT in accordance with the concession agreement and the contract documents (2). From the date of NTP 2 and for the duration of the contract term, the concessionaire will operate and maintain the project within the applicable operations and maintenance limits, which include the existing I-595 mainline, SR-84, and associated roadway infrastructure, and the project's capital improvements as detailed in the contract documents (2). In addition, the concessionaire will be responsible for carrying out the maintenance of all physical elements of the project and ultimately handing back the facility in a manner that is compliant with the hand-back requirements set forth in the contract documents (2).

Cost

The cost factor that FDOT found to be more complex on this project in the operations phase was contingency usage; this was not elaborated on in the interview (4).

Schedule

There were no schedule factors that the project team saw as more complex during the project's operation phase (4).

Technical

The technical factors that FDOT found to be more complex on this project in the operations phase were scope of the project, owner's internal structure, warranties, disputes, and technology usage (4).

Context

The context factors that FDOT found to be more complex on this project in the operations phase were public, political, owner, jurisdictions, maintaining capacity, work zone visualization, intermodal, marketing, local acceptance, and global and national economy (4).

Maintaining Capacity

FDOT ensured that the capacity would be maintained in the operations phase by putting a restriction and penalties clause in the concessionary agreement (4).

Intermodal

FDOT is purchasing buses for public transportation to be used on the new express lanes (4).

Financing

The financing factors that FDOT found to be more complex on this project in the operations phase were revenue generation, cordon and congestion pricing, PPP, global participation, and risk analysis (4).

Conclusion

Overall, this project has provided value for the State of Florida. The state has been able to accelerate construction by an estimated 14 years as a result of this transaction. In addition, public reaction has generally been positive. Although a number of projects in the United States have been affected by negative public perceptions of the entry into a long-term contract with a foreign-based private consortium, it appears that this was not an issue on I-595. These concerns may have been allayed because of the following: (1) the contract term is shorter (35 years versus 50 years or more); (2) toll rates are set by the state; (3) toll revenues are kept within the public sector; (4) the project involves the development of new capacity as opposed to an asset monetization; and (5) there was no “noncompete” clause that could impede the ability of FDOT or other public agencies to add capacity or transit alternatives near the project. It also anticipated that the project will support increased throughput and help reduce congestion along the busy I-595 corridor.

Observations of the Researcher

Greatest challenges

- FDOT was challenged to find the right level of oversight for the project.
- One lesson learned was that it is very important for the concessionaire to partner with local companies to learn the local culture and agencies.

The opinion of the researcher is that the reason for so few challenges is that most of them were taken care of and thought out in the planning stage. FDOT had finance, legal, and procurement experts to help guide them in the selection and contract document package before awarding the project to a concessionaire.

Opportunities for success

- A new process was developed to deal with inspections. The construction engineering and inspection on the project was the responsibility of an auditor for FDOT (in-house) to ensure that everything meets FDOT specification.
- FDOT and the concessionaire genuinely partnered to complete the project.
- Early construction projects (sound walls, greenway) were completed before starting major construction; this provided an opportunity for the concessionaire to figure out DOT processes and how to implement the contract as well as for both parties to become familiar with each other.
- Locating all partners in the same building has been extremely helpful; without this, the number of meetings and collaboration would have been very difficult.
- Workshops were held on construction between FDOT and the concessionaire.

- Having a public information officer in-house for the concessionary has been extremely beneficial in going out and giving presentations to the community with FDOT. The concessionaire has held fundraisers and has helped with community perception of a foreign company. FDOT was not able to do some of the things that the concessionaire has done to address community concerns.
- FDOT has had the benefit of full agency cooperation on the state, regional, and local levels from the government

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Lewis and Clark Bridge Deck Replacement Project

Introduction

The Lewis and Clark Bridge Deck Replacement project over the Columbia River between Washington and Oregon was completed in 2004. It is 5,478 feet in length with 34 spans carrying 21,000 vehicles per day. The cost of the deck replacement was split evenly by both states. The original bridge was built in 1929, and at the time of construction, it was the longest and highest cantilever steel truss bridge in the United States. To extend the life of the existing bridge by 25 years, full-depth precast deck replacement was designed and executed. Total funding from all sources for this project was \$29.8 million. The final total value of the contractor's contract for

the project was \$24 million. When the bridge had full closure, the remaining funds were used for other services such as overnight ferry operations and medical emergency helicopter (medevac) service.

Project Planning and Procurement Phase

The Lewis and Clark Bridge Deck Replacement project was in development for many years. The original project planning, including public hearing and design, began in 1993. Planning was put on hold in 1994 because the project team could not acquire public consent. Project planning and design restarted in 2001. The project was advertised and the construction contract was awarded in 2002. The public consent acquirement process was completed in 9 years.

The project delivery method for this project was design-bid-build (DBB). When the project planning began in 1993, innovative project delivery methods, including design-build (DB), to accelerate the project schedule were not available. In 2001, when the project planning and design were again discussed, the process for the project was too far advanced to be a good DB option. Therefore, the owners, Washington DOT (WSDOT) and Oregon DOT, selected DBB best value for the project delivery method.

Cost

Public satisfaction was the major driver for this project to require a more-complex construction strategy. The easiest and fastest construction could be achieved by full closure of the bridge during the whole duration of the project. However, the bridge was the only connection between Washington and Oregon within a 1-hour driving distance along the border line of the states. Many residents on the Oregon side commuted to Washington and had limited medical services available to them. If the bridge were to be fully closed, the Oregon residents would have only

very limited medical services and have commuting problems. Therefore, to reduce project impact on the public, a partial closure—single-lane closure during the day and night closure—was chosen for the project. The partial closure, however, would lead to a long project duration. To avoid a long duration, accelerated construction was required, which in turn might lead to an increased budget. To accommodate to on-time construction under a controlled budget, an incentive contract was selected for the project delivery method. There were two types of incentives in the contract: bid incentive and early completion bonus. The bid incentive consisted of the number of hours of single lane closure and the number of days of night closure, and a certain amount of bonus was given for early completion.

The trade-off between a better product with less public impact and a higher project cost affecting the design method was another source of complexity. The project team had to continually look for design solutions to reduce public impact without increasing the project cost too much, even though cost was not the project team's major concern.

Incentive provisions in the bid packages that were prepared during the planning and procurement phase helped to control cost and schedule during the construction phase. The project team's open attitude to the contractor's idea to build the project with innovative and better ways led to obtaining permission to use technology new to WSDOT. New technology saved \$10 million from the internal estimate and resulted in even better quality.

Schedule

One source of schedule complexity is that construction needed to be done within a reasonable time frame with limited traffic impact. Milestones drove project delivery method and risk. The project team needed to meet early completion for milestones and time to open the bridge to the

public. Therefore, the project team had to manage the project schedule in depth to make sure to meet the bridge closure requirement, even though the contractors had schedule control responsibility. Before every closure, night or weekend, the project team required that contractors submit an in-advance closure notice.

A clear distribution of the authority and responsibility of the participants was another source of schedule complexity. When promises to the public about times to open the bridge for traffic were announced through radio or websites and published by local papers, these promises had to be met. The authority and responsibility of the participants must be unambiguous to respond to any kind of situation.

The construction strategy reduced the time that construction on the bridge affected traffic while not changing the overall work schedule. The contractor revised the placement procedure by using self-propelled modular transporters (SPMTs) with a specially designed steel truss frame for lifting and transporting that enabled contractors to meet the scheduling constraints. The SPMTs moved the new panel to the top of the bridge, removed the old panel that crews had just cut out, and then lowered the new panel into place before taking the old panel off the bridge. Again, by using the SPMTs, construction time on the bridge could be reduced, which minimized traffic impact on the public, even though the overall schedule for the bridge work remained unchanged.

Along with the new technology, partial closure—night and weekend—was the tool used to manage timeline requirements.

The inclusion of early completion provisions in the bid packages helped to meet milestones. Also, the project team developed a 40-point checklist for surveying the size of decks to ensure that the deck replacement work could be done within an 8-hour work shift.

The project team developed a protocol plan to manage the preconstruction and construction strategy in regard to timing of action, responsible personnel to act, backup plan, and things to do first. This protocol plan clarified the authority and responsibility of the participants effectively.

Technical

Contract formation such as use of incentives and A+B bidding was a source of technical complexity for WSDOT in that they were new forms of delivery that the project team had never experienced before.

The design of the project was executed by in-house design staff. The in-house design staff experienced difficulties because the project had a very complicated technical design, and modeling did not accurately predict bridge behavior. The complexity of technical design and constructability was an issue. In the design phase of the project, the method of concrete placement was changed from standard cast-in-place concrete to precast, which made the whole process complex. The applicability of SPMTs for the delivery and removal of deck units was dependent on site-specific constraints and was discussed with SPMT suppliers in the early planning stage.

Existing conditions made the project more complex from a technical perspective. Given the historical nature of the bridge, one requirement was that the bridge must look the same after construction. In addition, the bridge was a steel structure over 60 years old, and the as-built drawings were inaccurate. Technical requirements also included the water quality (construction over the water and rain drainage issue), which must be kept the same as before construction. The

original structure also served as a home for birds, and the bird nests that were present were protected by law.

The work shifts of the owner's traditional project team required restructuring because of the time constraints caused by night and weekend closure.

Early review and analysis of the structure resulted in development of and public support for a precast option. The precast option had more risks to delivery and required significant effort to review constructability to make sure project elements could be built within the agreed-upon constraints. Issues raised in review were used to develop a management and contingency plan for use as the project was implemented.

The project team went through each step of night closure work with contractors to make sure the work was doable in an 8-hour work shift. The project team broke into pieces each step of construction constructability, had specific reviews in advance, and prepared a what-if plan. When responsibility is high, this kind of detail is required. The existing protocol plan was enhanced for emergency situations in the owner's internal structure.

Context

Minimizing the impact on the public drove design options. It took over 8 years to get consent for how the bridge would be constructed from public stakeholders, and the significant driving time associated with detours for bridge traffic initiated the complexity of the project from a context dimension point of view. The owner had to seek solutions to minimize traffic impact. User benefits were the major driver to go with a more-complex construction strategy such as using an incentive contract, which the owner had not experienced before, as well as night and weekend full closure of the bridge and precast deck replacement. When the bridge was fully closed, other

services were prepared. Such services include medevac and supporting funds to an existing ferry service to operate overnight.

The project was a very high impact project for the small local community, which drew much public concern. Prompt notification of the public of the project and its progress, particularly those matters directly affecting the public, was a challenge and made the project complex.

The project team prepared several options concerning construction methods for the public to choose from to manage the public's needs and expectations. The project team used a small physical model of the bridge that worked well to explain the bridge work process. Providing medevac and offering a closure predictability of a 2-week block were other tools used for managing public concern. The interviewee pointed out that excellent public participation was the biggest success factor of the project because the project team could hear the public's concerns. An extensive communication plan was accommodated for maintaining capacity, which refers to planning decisions made by the owner, such as lane closures, detours, and time of construction activities (i.e., nighttime, weekends, and so forth). The communication plan included a website updated daily, live webcam, local papers with weekly calendar, phone line to the public, highway advisory radio, and e-mail and text alert (on a sign-up basis).

Project Construction Phase

Cost

There was no formal cost risk analysis for this project. Cost control was not the biggest concern of the project team. However, because of the uncertainty of the estimate formation and new

technology to replace the deck, early identification of construction issues was key for cost control.

Incentive provisions in the bid packages that were prepared during the planning and procurement phase helped to control cost and schedule during the construction phase.

Collaborative work with contractors in the early stage helped to solve problems with less money and no significant impact to the structure or the public.

Schedule

As there was no cost risk analysis, there was no formal schedule risk analysis for this project. However, because of the importance of the bridge closure, schedule risk was the source of complexity.

Milestones and schedule control were sources of complexity, too. Schedule control was under the contractors' authority and responsibility. So, the contractors had to manage their schedule more in depth to ensure meeting closure requirements. The contractors also had an in-advance notice requirement for bridge closure.

The project team set up a communication plan to reduce schedule delay risk caused by miscommunication or late response among the project team members. Also, the project team trained contractors and internal personnel to provide notification of problems early so that the problems could be solved at an early stage, which resulted in saving money and having less impact on the schedule in most cases. One of the tools the project team used for early notification was the use of camera phones to send pictures of problem parts right away to the personnel who had the appropriate responsibility or authority to start thinking about how to fix the problems.

A postproblem meeting was another tool used whenever the project team faced milestone problems. Along with preconstruction strategy, postproblem meetings made the deck replacement procedures faster and better.

Seeking solutions actively for contractors was a tool to facilitate schedule control. The project team actively involved and coordinated local authority, police, and Oregon DOT to minimize schedule impact from outside.

Technical

The source of technical complexity from reviews and analysis in the design phase also was present in the construction phase.

Interpretation of contracts and tolerance of surveying accuracy were issues that arose between the designers and contractors because some provisions of the incentive contract were new to both sides.

Some tools (going through each step of work to make sure it is doable in a timely manner) from the design phase also were used in the construction phase.

Collaborative teamwork to resolve problems focused on only technical solutions (how to do this) and was the first step in dispute resolution. The matter of who was responsible for paying was discussed later.

Context

Same as design phase.

Technical

Same as design phase.

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New Mississippi River Bridge, St. Louis

Introduction

The New Mississippi River Bridge project in St. Louis, Missouri, and East St. Louis, Illinois, consists of building a new long-span, cable-stayed bridge of four lanes across the Mississippi River 1 mile north of the existing Martin Luther King Bridge. In addition, the project includes a new North I-70 interchange roadway connection between the existing I-70 and the new bridge, with further connections to the local St. Louis street system at Cass Avenue. On the Illinois side, the project includes a new I-70 roadway connection between the existing I-55/I-64/I-70 Tri-Level Interchange and the main span and significant improvements at the I-55/I-64/I-70 Tri-Level Interchange in East St. Louis, which will connect to the new I-70 connection leading to the main span. The 1,500-foot-long main span will be the second longest in the United States upon completion.

Crash incidence near the existing bridge is three times the national average, and congestion on the bridge ranks among the 10 worst-congested corridors in the country, so

redesign and expansion of capacity was critical. Severe traffic conditions (capacity, safety, and mobility) also made the schedule a priority.

This report will detail the processes used to make decisions during the project's planning and procurement, execution, and operations phases. Figure B.16 shows the alignment and phasing plan for this project.

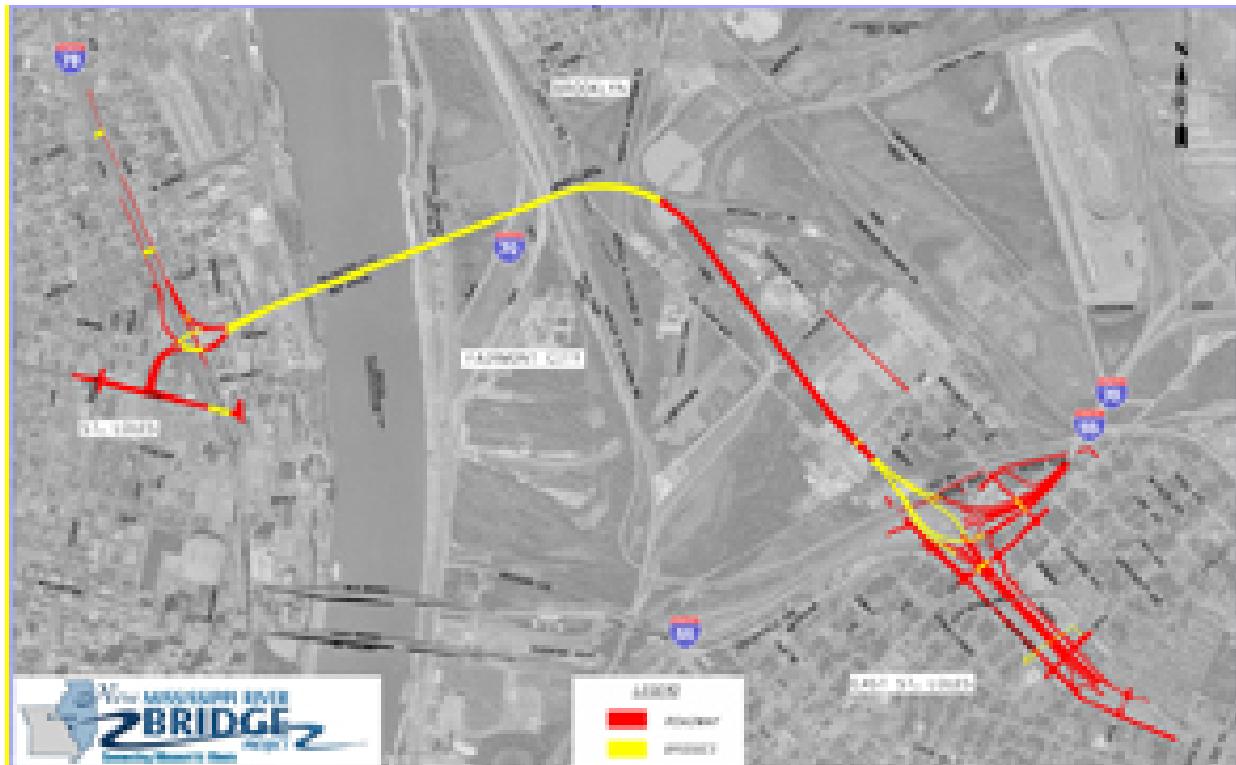


Figure B.16. New Mississippi River Bridge project.

Project Planning and Procurement Phase

Action Taken	Date
Final Environmental Impact Statement (EIS)	March 2001

Record of Decision (ROD)	June 2001
Final EIS reevaluated	November 2008
Final design contract awarded	March 2009
Main span (bridge) Request for Bid	Late 2009
Main span (bridge) contract award	November 6, 2009
Illinois approach contract award	January 2010
Missouri approach contract award	February of 2010
Construction complete	Expected 2014

The total project costs are expected to be \$640 million. The remaining design and construction of the original referred alternative will be the subject of a future phased development in that the total project cost is now estimated to be \$2.66 billion.

The project delivery method used on this project was design-bid-build (five design contracts and 31 construction contracts). During procurement, the project team allowed an alternative technical concept (early contractor involvement) on the Missouri approach and main span bids. There is a project labor agreement for the Illinois approach project.

Cost

The cost estimate development process started with “big picture” plans. There was a contingency for each major work item and for each segment. These contingencies were refined as final

designs were developed. This allowed for reallocation between segments as contracts were let. Overall, there was a 20% contingency on the Illinois approach and a 15% contingency on the main span, with smaller contingencies for the other segments.

The risk analysis and assessment was a very thorough, formal process and was started early in the planning and design phase. Use of the formal risk analysis process helped the team identify risks at an early stage when mitigation steps could still be enacted. A good example is the identification of potential schedule delays involving coordination of design with the railroads. The team devoted \$50,000 to \$200,000 from the project contingency funds to help railroads and other utilities complete designs and project reviews necessary to maintain the project schedule. The project team had to redefine feasible (i.e., fundable) project phases and redesign the first phase project to fit available funds. Illinois used program money plus a special appropriation from a capital bill (“use it or lose it” money), so cost control and getting the project designed and awarded quickly were key. The project team instituted contractor specialized plans as defined in the Special Experimental Project No. 14 (SEP-14) report. Material prices were monitored. For instance, steel prices were volatile during the design phase, which made tracking estimates and contingencies difficult for that part of the work. Overall, material prices or construction inflation were not a major concern. For the Phase 1 project, the user cost to benefit ratio was calculated at 23:1.

The team used Crystal Ball software for contingency planning per FHWA guidelines. Experience and advice from FHWA indicated that contingencies were too low for projects of this scale, so the process helped identify realistic values.

Major project risk analysis and mitigation process was new to the Illinois team. The Risk Management Plan was developed early in the process and reviewed weekly, which forced the

team to identify potential problems early in the process and develop solutions before cost or schedule were affected. Use of this tool allowed the team to get started early with railroad and utility issues that could have affected design, increased costs, and delayed the schedule.

The team adopted a practical design philosophy that helped the project stay under budget and on schedule. Practical design also allowed for design revisions to minimize ROW takes as a cost and schedule risk control mechanism. During procurement, the project team had a process for allowing contractors to propose Alternative Technical Concepts in an effort to get good value decisions in the procurement process. The team also used independent contractor reviews and value engineering.

Colocation of a dedicated, empowered project team allowed for rapid design development and responsiveness to changes.

Schedule

The schedule was critical because of special appropriations (i.e., use it or lose it funds) that were going to expire if the project did not move forward. This fact was communicated to stakeholders, which helped everyone understand the need for developing a project plan that fit the budget. The support of the Missouri DOT (MoDOT) and Illinois DOT (IDOT) directors was critical to keeping the schedule moving quickly once a financially feasible project was established. A formal risk analysis and planning process informed decisions on the schedule and helped establish milestones. The schedule process was linked to cost, budget, and risk as described in the cost section above.

Schedule control was critical to control costs and keep the project affordable. The project required more integration than was typical for most IDOT and MoDOT projects. The integration

and well-developed project plan added credibility to the project when funding sources and project schedule were integrated and communicated. The project team was successful in communicating to stakeholders that if the community waits or the project gets delayed by any stakeholder group, they run the risk of not having a project.

The main span design schedule was cost loaded, and consultants developed a master design schedule in Primavera. The contractor's schedule (main span) for construction is a resource-loaded critical path method (CPM) schedule using P6, but it is not used for payment schedules. Project team meetings were used to manage the interface between discrete work packages in the design phase. Earned value analysis was used for the design of the main span, which was unique to this project. The schedule was affected by the need to maintain local access on the East St. Louis, Illinois, side as well as by coordination with railroad and utility design and the review process.

Technical

Because the original project was broken down into phases to accommodate available funding, the Phase 1 design needed to maintain compatibility with the design intent for subsequent phases. Another goal of the design team was to avoid utility and railroad conflict and to minimize ROW takes. This was an intentional design goal meant to mitigate cost and schedule risks. Because the project is in a seismic zone, substructure and superstructure designs are more complicated than for nonseismic zones. Seismic codes were used, and the main span was designed for a 2,500-year seismic event. There were innovative seismic design elements intended to prevent liquefaction in the substructure soils.

The main span design had to allow channel clearance for two-way barge traffic in addition to barge ports. The primary geographical factors that affected design were the zero rise constraints in the channel and the low water table in some sections of the project. Requirement for zero backwater rise affected bridge tower design and created a need for some redesign and negotiation with the Army Corps of Engineers. Wind design on the towers was also complicated. The project designer had to redesign vehicle barriers to reduce wind loads.

To ensure a high value design, the main span and some approach work used alternative technical concept proposals from contractors during procurement. During the construction phase, partnering meetings were held with the contractor on the main span to facilitate project communication and the continued support of value-added activities. On Missouri approach contracts, the team decided to use contract language calling for the standard MoDOT process for resolving disputes. For the Illinois approach and the Tri-Level Interchange, there is a project labor agreement. Federal-aid projects allow more flexibility on dispute language and how contracts are structured, so the process is not as complicated as it might seem.

DBE goals were considered during design and development of work packages. There are also special contract provisions for achieving social and environmental responsibility goals. The prime designer (HNTB) brought in the National Constructors Group to perform an independent constructability review during the design phase. This group acted as a subcontractor to the prime designer. A major source of technical complexity was caused by the presence of a flood wall on one side of the main span and a levee on the other side. This made contractor access very complicated during the construction phase.

MoDOT required a quality management plan from the contractor on the main span, which is not typical for DBB contracts. Waterproofing and moisture monitoring of the cable

stays was a primary design and quality control concern. In addition, the levee needs to be protected during construction and contractor site operations. There are no Environmental Protection Agency (EPA) sites in the corridor. There was a prior industrial site with high concentrations of lead in the soil, but it was decided to cap the site instead of remediate the soil so as to keep the project on schedule. The interchange designs required many design exceptions to new federal standards to fit into the existing corridor envelope. Designing to new standards would have increased cost and threatened the viability of the project. In particular, the Tri-Level Interchange required numerous design exceptions to fit within the existing corridor footprint. For instance, the roadway elevation was kept the same in spite of the need for 25 MGD (million gallons per day) pumps to keep the water table below the road surface. This elevation will require the relocation of well intakes and discharges during construction to keep the interchange operational.

High water levels and frequent flooding were a concern because of the location of the project. To communicate project outcomes to the public and the media, the team developed a fly-around video showing construction stages and related work zones. The project team decided to add aesthetic lighting to the bridge even though it was not required. The team also implemented acoustic monitoring technology for remote monitoring of the cable stays, which is currently an unfunded improvement (came out of contingency). The ITS ties into the existing regional system that is managed jointly by Illinois and Missouri.

Context

There was general stakeholder support for the project. Discussion focused more on what the bridge should look like than on opposition to the bridge. No group really opposed the project, but

several groups wanted input into the process. In the original project, the tolling option was contentious. Design changes that occurred in 2005 had to be communicated to the public, and expectations had to be managed to keep the project financially viable. Economic growth opportunities in East St. Louis were a factor in project planning, design, and procurement. The federal appropriation for the main span had a spend it or forfeit timeline, which created leverage in gaining public acceptance. In essence, the public option was between having the bridge more or less as designed or having no bridge at all, which helped keep the process moving along. The project team needed approval of local jurisdictions and statewide approval for use of Grant Anticipation Revenue Vehicle (GARVEE) bonds on the Missouri side. The nature of the project required compliance with dual state and FHWA requirements as well as cooperation with multiple jurisdictions, the state historical preservation officer (SHPO), EPA, and so on. Colocation of the project design team helped with coordinating the design for the six project segments.

Local access concerns created the need for well-developed and well-communicated staging plans and existing route support. The ITS system was integrated with work zone plans within both states. The ITS system helps to coordinate closures and peak-hour restrictions during construction. Work zone and staging issues are not a major issue considering the scope of the project because they have been well planned and communicated. The Illinois Hwy 3 interchange was added to the project scope to promote growth and access on the East St. Louis side of the river. One of the reasons for expanding the project to include the Illinois Hwy 3 interchange was an attempt to improve the East St. Louis tax base. Plans are under way for development at the Illinois Hwy 3 interchange in East St. Louis as well as plans for redevelopment in the North St. Louis area.

Emergency services are coordinated through frequent meetings with service providers.

There are standpipes included on the bridge to help address vehicle fires. The project team held a security workshop for the main span because major urban bridges are high-potential targets for terrorist attacks.

Issues with railroad ROW were identified in the risk analysis process. The taking of easements where billboards are located became complicated and resulted in a lawsuit to determine whether economic loss must be applied to easement agreements (decision pending). Maintaining access to local businesses and neighborhoods was critical. Also, the impact of the project on local employment was helpful in getting support and moving quickly on jurisdictional approvals. Project “marketing” and public relations were mostly handled internally. Because of archaeology sites within the project boundaries, the state archaeology society is involved, especially on the Illinois side. The SHPO section 4(f) process was involved on both the Missouri and Illinois side. Labor union influence, especially on the Illinois side, was an important context issue. The DBE mix in different labor classes was hard to establish, and getting DBE program trainees into the unions is a continuing problem. Availability of DBE labor is not an issue as much as union control of access to work.

Many utilities are involved near the location of the new bridge. The approach spans on the Illinois side crossed a major rail head that included several sets of tracks. The project team had to proactively manage the railroad and utility coordination, which was facilitated by the risk management process.

Some solar power is incorporated into the main span design, and the construction contracts include environmental and social responsibility language, but there is nothing particularly complicated about the environmental issues. The lead contamination was solved

simply with soil caps. The project needed SEP-14 approval for use of alternative technical concepts in procurement and was required to follow all FHWA procedures for major projects.

During the design and procurement phase, steel prices went down, which helped with contingencies and the overall project budget. There were some issues with flooding, and high water levels on the river went beyond what was anticipated, which has required the main span contractor to pull the barges off the project a few times in spring and summer. The contract requires the contractor to pull the equipment barges off the river when it is within 2 feet of flood stage, and the situation is being managed.

Financing

One of the major issues on the project was the wait for the transportation bill to be finalized. The Illinois governor signed a special appropriation bill in February 2008. The project really took shape after that action by the Illinois legislature and governor. The original project had to be scaled back (phased) because of the inability to identify a viable financial plan. The dual state appropriations in addition to program funds from both states and federal appropriations complicate the tracking of cost allocations to different project components and funding lines. Missouri used GARVEE bonds and program funding for state work on the Missouri side. Work on the Illinois side is funded through the transportation bill appropriation for main span approaches provided in the Illinois capital bill in 2008. Additional state appropriations have been designated for the Illinois Hwy 3 interchange on the Illinois side. Some of the construction contracts use 100% state program funds, while others have a mix of state capital appropriations, GARVEE bonds, and federal appropriations. The risk analysis and mitigation process discussed in the cost and schedule section was closely linked to financing and funding issues. There was a

need to move quickly and keep the project scope within available funding limits. Also, breaking the original project into “fundable” phases helped move the project forward.

Project Execution

The main span construction contracts were let in November of 2009, the Illinois approach work was awarded in January 2010, and the Missouri approach work was awarded in February 2010. All contracts are proceeding as planned, and project completion is on schedule for a 2014 opening.

Project Operation Phase

This project is approximately 4 years away from this phase

Summary

The project has benefited from flexible scoping into fundable phases, a practical design philosophy, colocation of a project team empowered to make project management decisions, and a formal risk analysis and mitigation process.

Observations of the Researcher

The project team appeared to be very unified and cohesive and had a common understanding of what was needed to keep the project viable. It is interesting to compare the New Mississippi River Bridge (NMRB) project with the Ohio River Bridges project in Louisville. The NMRB team appears to be very aware of the new funding realities of major complex projects and has taken steps to revisualize the project on the basis of these new realities. Design, cost, and schedule are outcomes driven by context and financing rather than project management inputs into an idealized project scope.

North Carolina Turnpike Authority: Triangle Expressway

Introduction

In 2002, the North Carolina General Assembly created the North Carolina Turnpike Authority to respond to growth and congestion concerns in North Carolina. Two of the nine authorized projects include the Triangle Parkway and the Western Wake Parkway, which together compose the Triangle Expressway. These two projects combine for a total of approximately 19 miles of new roadway on one side of Raleigh, North Carolina, as shown in Figure B.17. These projects will be North Carolina's first experience with modern toll facilities. Both projects were initially advertised in 2007, and completion is expected in 2011. The total awarded value of the project is approximately \$583 million.

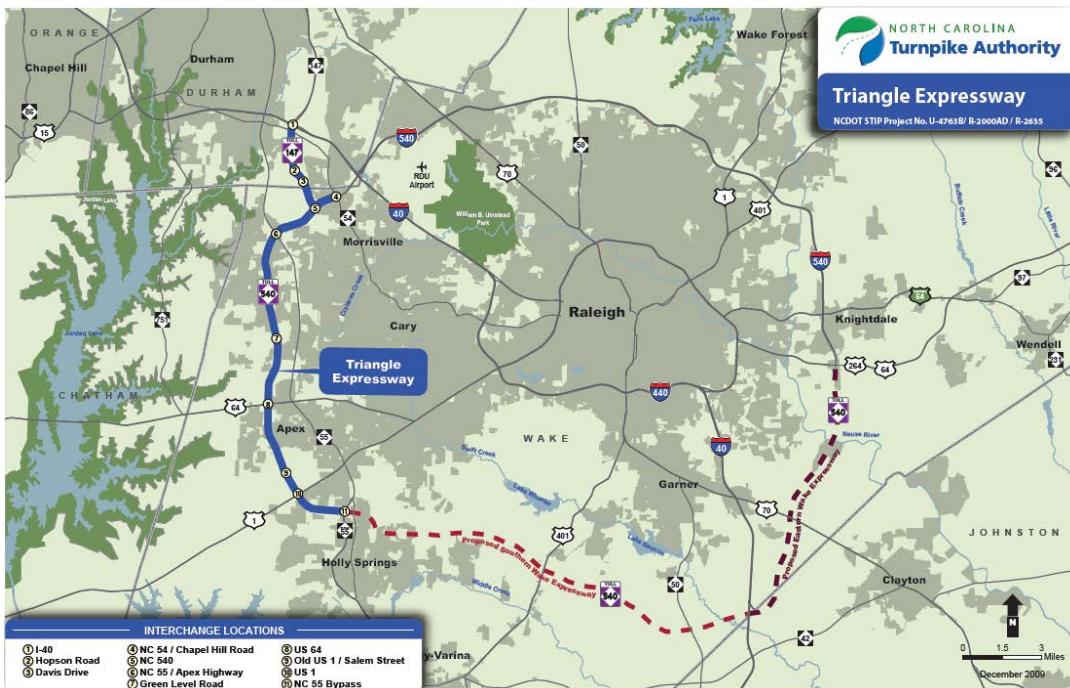


Figure B.17. Triangle Expressway (<http://www.ncturnpike.org/>).

Project Planning and Procurement

Cost

Having an accurate estimate of project costs for this project is important because bonds were used to finance the project. Several tools were used that included the FHWA project management plan and cost validation method and Crystal Ball software.

Schedule

During the procurement phase, there were some problems with the economy. This affected the schedule in that the bonds could not be obtained as quickly as previously believed.

Technical

This project is a design-build project; however, the North Carolina DOT (NCDOT) provided some design for these projects. On one projects, design was approximately 75% complete. There is a difference between how the DOT designs a project and the method used by the design-builder for the turnpike. The DOT considers that this may be the last chance to work in the area for a number of years. The turnpike authority, and therefore the design-builder, designs the project on the basis of traffic. The procurement process consisted of two steps. The first short-listed the bidders to three, and then two design-builders submitted during the second round. Before issuing the solicitation document sheet, the turnpike authority released draft solicitation documents and held meetings with individual proposers before issuing the final documents. In the meetings, the proposers could ask questions and point out conflicts between the documents. In the first meeting, there might be 100 questions, but by the second meeting, the number of questions was reduced to 10 to 15.

Context

This project is an extension of a loop around the city that would take NCDOT 25 years to have the resources to continue. The corridor for the project has been protected since the early 1990s. These projects are the first toll projects, so there was some opposition to the projects from the start. There has been less opposition as the projects have progressed and the public has been educated about the need. However, there are high expectations and a need to complete the project successfully as the first tollway.

Financing

Bonds are used to finance this project. There are two aspects of these bonds: (1) the capital cost (cover construction and ROW) and (2) operation and maintenance. Together, these make up the total cost of the project. The lump sum proposals from the design-builders were obtained before going to the bond market. The proposals included a provision for the price to be held 120 days from bid opening. During that time the turnpike authority would go to the bond market and secure funding. However, it is at this time that the market collapsed. The contractors were asked to extend their proposals for 1 year. The contracts were preliminarily awarded, and the design-builders were allowed to start design and obtain materials; however, there was no guarantee that the project would go forward and no notice to proceed. This was one of the issues encountered with bond financing during this time. The other issue was concern about cost overruns. NCDOT, through legislative action, agreed to pay for any cost overruns by the authority. This helped with the market rating on the bond market.

Project Execution

Cost

The design-builder is required to have a cost-loaded CPM schedule, which is updated every 2 weeks. The activities within this schedule cannot exceed 20 days or \$500,000 (with a few exceptions, i.e., a bridge deck pour). There are currently more than 3,000 activities, each with its own cost curve, and this is the basis of payment.

There are several contracts on this project in addition to the design-builder contract for the design and construction of the roadway; these include contracts with the landscapers and the company installing the toll and ITS. The design-builder contract includes a completion incentive clause. This is a two-phase incentive in which the design-builder receives an additional \$2 million if everything done within its control is completed on time. The design-builder can also get an additional \$1 million if the entire project, including activities under another contract, is completed on time.

Schedule

This project has a greater focus on schedule than do normal projects because of the urgency to open the roadway and begin collecting toll revenue. The project schedules are very short and aggressive, with \$2–\$3 million paid out per week. The turnpike authority has a dedicated scheduler who watches for changes, the impact of a change, and any impact the turnpike authority might be having on the project schedule. Schedule plays a factor in every decision made on the project, so much so that the design-builder and turnpike authority are continually watching for opportunities to accelerate, and if acceleration is needed, when the cost of not accelerating is more than the cost of acceleration.

Technical

Currently, only three people work for the turnpike who focus on construction, so staffing is limited, which has led to several issues. The design-builder is required to meet both American Association of State Highway and Transportation Officials (AASHTO) and NCDOT requirements, and in some cases, these requirements are not the same. Although NCDOT reviews the designs, the turnpike authority examines the reviews as they are returned to make sure that they are in accord with the spirit of design-build and the project. In addition, one independent company is paid to conduct quality assurance, and another independent company is paid to conduct quality control.

This project includes formal partnering with meetings every quarter. This has worked to the point that on the job site it is hard to tell who is who except for the differently colored vests and hard hats. This project has a dispute resolution board of three people. One person was selected by the turnpike authority, one by the design-builder, and a third by the other two on the board. This board meets every quarter even if there is no dispute. In addition, the board receives meeting minutes and other documents to keep up to date on the project. So far, nothing has escalated to the point of needing review by the board but yet it is “good knowing they’re out there.”

The design-builder is using stakeless surveying and GPS modeling, which caused some concern over how to conduct quality control and quality assurance. A provision was incorporated to allow for these techniques, and it requires that the design-builder provide the inspectors with the equipment needed to do QC/QA with this technology. This decision has increased productivity and has allowed for real-time as-built plans to be developed.

Context

The corridor for the project has been protected since the early 1990s. The NCDOT previously purchased ROW has helped to reduce the ROW funds required and has allowed for the design-builder to begin working. However, some ROW still needs to be acquired, which is being completed by the turnpike authority. To help with this effort, the design-builder created a priority list for the authority to use. The design-builder and the authority have also been flexible in their design and allowed for some modifications to be made as ROW issues come up.

Review and approval by the local municipalities is required for plans and utilities, some of which are owned by the municipalities. This has created some issues in that not all of the municipalities are familiar with design-build. The authority developed a system in which the municipalities became involved during the preliminary planning stage.

Project Operation

This project is not yet complete.

Researchers Observations

The researcher observed that this is a high profile project with a number of high expectations set both by the authority and for the authority. The authority and design-builder, as well as all the other parties involved in the project, are working to make sure that they meet those expectations. Surviving the downturn in the market, obtaining bond financing by the design-builders, extending the period that their bids are valid, and providing gap funding by NCDOT shows a

commitment to this project by all parties. The size of the staff at the authority is interesting. The researcher understands that the staff has changed somewhat over the course of the project to fit the needs of the project phase, but to be in construction with only three construction personnel is unusual. One reason the limited staffing was adequate might be the use of the design-build method and the hiring of trustworthy design-builders and consultants.

Northern Gateway Toll Road, Auckland, New Zealand

Introduction

The Northern Gateway Toll Road (see Figure B.18) was the first toll road in New Zealand to be fully electronic, and the construction project was one of New Zealand's largest, most challenging, and most complex to date. It extends the four-lane Northern Motorway 7.5 km further north from Orewa to Puhoi through historically rich and diverse landscapes, steep topography, and local streams, and it provides an alternative to the steep two-lane winding coastal route through Orewa and Waiwera. The \$360 million extension of State Highway One was constructed to provide a straight and safe drive between Auckland and Northland. The project was delivered by the Northern Gateway Alliance, which comprises Transit New Zealand, Fulton Hogan, Leighton Contractors, URS New Zealand, Tonkin & Taylor, and Boffa Miskell. The road opened in January 2009 and has become a visual showcase of environmental and engineering excellence.



Figure B.18. Map of the Northern Gateway Toll Road.

The project is composed of seven bridges totaling 1.1 km in length, two eco-viaducts built to protect nature corridors at Otanerua and Nukumea, a local road bridge at Hillcrest, 380-m-long twin tunnels at Johnstones Hill (see Figure B.19), and five major culverts. At its peak, about 300 people worked on the project. The project moved more than 4 million meters cubed of earth, covered 130,000 meters cubed of road surface, and used 60,000 meters cubed of concrete.



Figure B.19. Twin tunnels at Johnstones Hill.

The benefits to the public are the ability to bypass usual congestion spots and to have a more direct, straighter, and shorter route between Auckland and Northland with safer passing opportunities. The toll collection has easy payment options with an electronic toll collection that can automatically deduct tolls with a state-of-the-art electronic collection system (see Figure B.20). After setting up an account, users do not have to stop to pay their tolls.



Figure B.20. Electronic toll booth.

Planning and Procurement Phase

Project investigation started in the early 1990s, got put on hold, and started again with obtaining consents (permits) and designations at the end of 2003. The remainder of 2003 and 2004 were used for procurement. Funding for the project was not yet in place at the start of the project, and the use of existing roads as temporary bypasses for traffic was challenged in court. Extension of the use of these alternative roads was approved on a year-by-year basis, depending on proof of construction of the Northern Gateway (see Figure B.21). As the Highway Authority did not have the required funds, a business case was made to the Treasury, which finally lent the remaining funds to the Highway Authority in exchange for tolling rights for 35 years during the design phase. The risk for this income was transferred to the Treasury.



Figure B.21. Roadway construction.

Technically challenging aspects of the project included tunneling, which had not been done by the agency in decades, as well as dealing with a largely unknown geotechnical situation

and building on environmentally protected land. Construction of the road through a protected area was challenged, and solutions were developed to minimize the environmental impact, such as a twin tunnel (see Figure B.22).

All the uncertainties in the project, which included the necessitated early start of construction, made design-bid-build delivery impossible; essential risk transfer was deemed to make design-build too expensive. In addition, although a PPP would have been possible from a business case point of view, there was considerable political unease with this method of delivery. Alliancing, however, gave the option to start construction after a little bit of design. The alliance partners were aware that approval of the money was pending and that the risk that the project could be halted was shared. “Pure” alliancing was used, as opposed to competitive alliancing (used in Australia) or partnering (used in the United Kingdom). This version is true cost share and risk transfer; in the United Kingdom, alliancing is practiced as partnering , that is, there will be working arrangements, but the risk is still placed on a particular party. Pure alliancing versus competitive alliancing differs in procurement. In pure alliancing, the owner short-lists to a preferred supplier on nonprice attributes, which then starts the design and produces a target outturn cost (TOC). In a competitive alliance, after two competing teams produce a TOC, the evaluation is done, which incorporates a cost component. During design, the suppliers are paid a fee for intellectual property. After the award, both forms of alliancing become “true” alliances, and both cost and pain are shared.



Figure B.22. Tunneling operations.

Alliance Partners

Since 1997, when the Environment Court designated the land, the Northern Gateway Toll Road has been crystallizing. A road passing through an historically rich and diverse landscape needed to be clearly thought out and constructed with care and wide community consultation (see Figures B.23 and B.24).

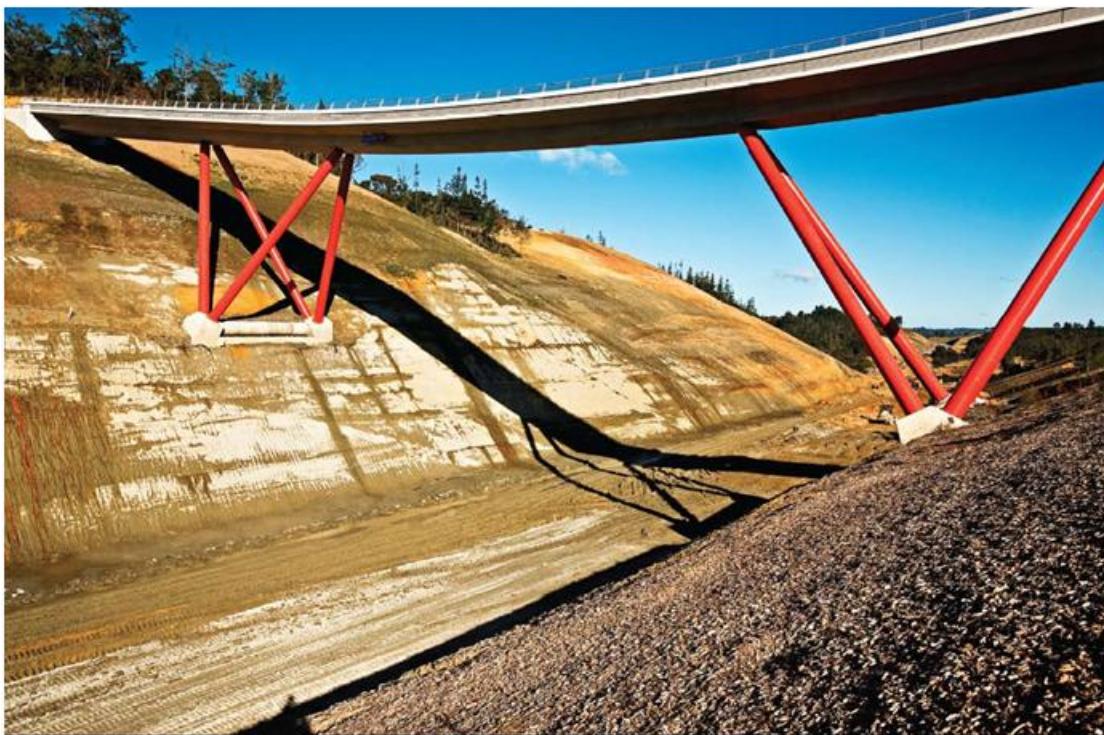


Figure B.23. Bridge construction.

The Northern Gateway Alliance (NGA) was formed by Transit New Zealand in 2004 to design, manage, and construct the Northern Gateway Toll Road. Eight organizations make up the alliance, each member playing a critical role in ensuring an innovative, efficient, and cost-effective project. The alliance partners are owner-participant NZ Transport Agency (formerly Transit), Fulton Hogan, Leighton Contractors, URS New Zealand, Tonkin and Taylor, Boffa Miskell VSL, and United Group Ltd. Within the alliance, there are multitudes of specializations. NZ Transport Agency develops, manages, and maintains the country's state highways. Fulton Hogan is a dynamic, diversified contracting company active in New Zealand, Australia, and the Pacific Basin. Leighton Contractors is a publicly listed Australian contracting company delivering projects to governments, major corporations, and other clients across Australia. URS New Zealand is a professional services company providing engineering and environmental

expertise across New Zealand, Asia Pacific, and in other parts of the world. Tonkin & Taylor is a New Zealand-owned, international environmental and engineering consultancy. Boffa Miskell is a leading New Zealand environmental planning and design consultancy providing integrated solutions for public- and private-sector clients, and suballiance member VSL brings to the alliance specialist international knowledge of large-span bridge engineering and construction methodology. Suballiance partner, United Group Limited (UGL), also brings specialist international knowledge to the Northern Gateway Toll Road. UGL, which is in charge of completing the project's tunnels and mechanical and electrical services, is a leading Australian engineering and services group operating throughout Australia, New Zealand, Asia, the United States, and the United Kingdom.



Figure B.24 Diverse construction landscape.

Execution

The alliance started in December 2004 and finished 5 months earlier than the project timeline of 55 months. The toll road has been in service for 1 and 1/2 years (since August 2010) and is viewed as a success by all involved.

The project started as planned and ended ahead of schedule and below cost. The alliance model, which included whole-life costing, worked well. The partners did not veto design decisions that cost more initially but had a lower life-cycle cost, and they had a genuine desire to deliver a good product and create a good image.

Technical issues were resolved by using best practices from around the world (experts visited other countries). The contextual issue of public perception, including environmental concerns and NIMBYs (not in my backyard activists), was resolved by hiring a full-time public liaison person who initiated monthly newsletters and site visits for the public, handled complaints, and so forth.

The project has three key result areas (KRA)—environmental, social, and economic—and key performance indicators (KPI) to assist with implementation and performance measurement. The three key result areas are supported by 16 KPIs, with progress against them monitored monthly. The project has tracked ahead of its KPIs for forecast time and cost to completion. The Legacy – Skills Development KPI is one of five measures under the “social” KRA and is the mechanism for measuring the project’s contribution to developing the skills of its staff and therefore contributing to the wider construction industry and society as a whole. Typical construction industry practice for project work is to rely on the recruitment of skilled plant and equipment operators from within the industry. However, in response to the national shortage of skilled operators, the NGA took a unique approach by seeking to attract and train

people from outside the industry and providing them with the skills needed to join the project as skilled operators. NGA also provided training for people hired from within the construction sector to further improve their skills (see Figure B.25).



Figure B.25. Construction workers on job site.

Operation

The Northern Motorway sees heavy traffic: the section between Esmonde Road and Cook Street has an annual average daily traffic count of more than 100,000 vehicles per day, with around 155,000 vehicles per day crossing the Harbour Bridge. The toll road's operating report for the period July 1 through December 31, 2009, shows that the 6-month total for all traffic using the road was 4.2% higher than forecasted, bringing the total number of journeys since the toll road opened in January 2009 to 4.3 million, or 3% ahead of the forecast.

Wayne McDonald, NZTA Regional Director for Auckland and Northland, said the higher-than-forecasted traffic volumes had contributed to greater than expected revenue collection, with paid toll revenue 4% ahead of budget.

Key results for the six months from July through December 2009 include the following:

- The overall compliance rate (percentage of trips that have been paid) on the road has remained constant at 94%.
- Total revenue released to repay debt for construction of the road was \$2.9 million, about 4% higher than initial forecasts.
- The average cost per transaction to operate the tolling system for the 6-month period was \$0.78.
- Nearly half (49%) of trips taken on the toll road during the 6-month period were by prepaid account holders.

Mr. McDonald said that several changes had been introduced to improve services for toll road customers that included extending the toll payment period from 3 to 5 days.

Tolls for the Northern Gateway Toll Road are collected electronically at an automated toll plaza just north of the Grand Drive interchange. The automated toll plaza uses automatic number plate recognition to identify the vehicle, from which the number plate is optically read, and details are checked against the New Zealand Transport Authority's (NZTA) database. Any prepayment made or account open for that particular vehicle is identified at the plaza. Additional sensors detect the size of the vehicle to help prevent misreads of registration plates and to notice plate swaps between cars and trucks. In the event the computer system needs assistance in recognizing plates or needs help for any other reason, data are sent to the NZTA office in Palmerston North for human analysis.

Awards

- *Northern Gateway Toll Road Awarded Cement and Concrete Industry Sustainability Award.* The award, which is part of the Concrete3 initiative launched in 2007 by the Cement and Concrete Association of New Zealand, acknowledges companies whose product, program, or initiative demonstrates excellence in environmental, economic, and social sustainability. Among numerous other features, the project achieved top honors in concrete sustainability for the concrete lining in the road's twin tunnels, which made extensive use of polypropylene fibers for fire resistance, and its bridge structures, which used time-saving match-cast technology for the first time in New Zealand.
- *Roading New Zealand Supreme Award and the Shell Bitumen Excellence Award for a Major Road Project.* Roading New Zealand chief executive Chris Olsen said that the awards judges considered the Northern Gateway Toll Road to be an excellent example of a project that was meticulously planned and executed under a truly collaborative model. Further, it was considered a testament to NZTA's courage to embark on major and high risk projects using this form of contractual arrangement, and it also demonstrates the New Zealand contracting industry's ability to deliver these complex projects very successfully.
- *2009 ACENZ Gold Award of Excellence.*
- *2009 IPENZ Arthur Mead Merit Award for Environment and Sustainability.*
- *2007 Supreme Environmental Award.*

Lessons Learned

All projects have areas that can be improved upon. On reflection, key areas identified were the following:

- *Communication.* While every endeavor was made to create open and transparent communication, this was sometimes challenging with a fast-track project, as not everyone gets the information. Communication is an area that requires continuous assessment and improvement.
- *Facilitation.* Creating one culture out of six cultures has a big learning curve. It is important to have a facilitator to coach people to learn to work together and develop their interpersonal skills.
- *Learning curve.* Alliance is a new way of working in New Zealand, and it will take a while to gather momentum as more people become exposed to this way of working. It is a process of change, and throughout this process, there is an enormous amount of learning.
- *Document management system.* The single-point data system takes time to adjust to but has become central to transparent and up-to-date information. Many people were working on this project, and once the processes were understood, access to information became easy.
- *Whole team engagement.* Ensuring that subcontractors feel like part of the team and are involved in decision making for the project when appropriate is important.
- *Design change monitoring.* It is important to monitor the continuous changes to the design to ensure that all decisions add value to the project, especially in an alliance in which all day-to-day decisions can be made on site without external approval.

Texas State Highway 161, President George Bush Turnpike Western Extension

Introduction

Texas State Highway SH-161 was proposed in 1957 when the Dallas outer loop was discussed by the Dallas Area Master Plan Committee (2). Since that time, years of environmental planning, permitting, legal delays, and ROW acquisition have taken place to lead to the state of the project today. The project consists of a 11.5-mile-long tollway. The magnitude of the project, which includes the cost and the entities involved, and its innovative financing are characteristics that make the project complex.

Planning and Procurement Phase

The planning of SH-161 began in the late 1950s, and various stages of planning have occurred over the past 30 years, with the vision of creating the western portion of the second transportation loop around Dallas (2). The project will serve as a major direct link in the Dallas/Fort Worth regional transportation network. It will relieve congestion along the SH-360/SH-161 corridor, thus reducing fossil fuel usage and offering considerable time savings over alternative routes.

In 1998, the Texas Department of Transportation (TxDOT) began to acquire ROW for the project (2). During the planning process, and after TxDOT had begun construction in what was determined later to be Phase 2, the North Texas Tollway Authority (NTTA) proposed that SH-161 be converted to a tollway. The implementation of tolling on SH-161 supports the overall project's needs by generating revenue for the operation and maintenance of SH-161. Tolling SH-161 allows for construction of the main lanes 5 to 10 years earlier than previously programmed by the State of Texas. A market valuation process in 2007 completed between NTTA and

TxDOT determined the approach of the project, and it was divided into four phases for purposes of managing and expediting the design and construction process [the phases are displayed on the map shown in Figure B.26 (4)]:

- Phase 1 includes the frontage roads and cross streets from I-20 to directly north of I-30 as well as SH-183/SH-161 interchange improvements.
- Phase 2 consists of frontage roads, cross streets, slip ramps, and portions of the main lanes between I-30 and SH-183, which are being constructed by TxDOT. NTTA is constructing all toll gantries for Phase 2. In August 2009, two main lanes in each direction within Phase 2 were opened to traffic, and work continues on the remaining portions.

- Phase 3 includes slip ramps and portions of the main lanes between I-30 and SH-183.



Figure B-26. Project location.

TxDOT completed Phase 3h the exception of the toll gantries (see Figure B.26).

- Phase 4 is the responsibility of NTTA and includes direct connection ramps, slip ramps, frontage roads, cross streets, and the main lanes between I-20 and Carrier Parkway, directly north of I-30.

Portions of the project were already complete or being constructed by TxDOT (including Phases 1 and 2) at the time of the market valuation process. Both NTTA and TxDOT are responsible for sections of Phase 3, and NTTA is responsible for Phase 4. On April 20, 2008, NTTA and TxDOT executed an agreement that provided for a negotiated market value for the project. The agreement includes a \$458 million upfront payment to TxDOT from the NTTA. Beginning in the 53rd year after the execution of the agreement, NTTA and TxDOT will equally share (50%-50%) all net revenues from SH-161. Before the 53rd year, NTTA will operate and maintain the tollway and generate the revenues from it. TxDOT will continue to maintain and operate the frontage roads, which were part of Phase 1 and portions of Phase 2 of the project (2).

Cost

KBR executed the PS&E documents for Phases 1–3 of the project. Cost implications from accelerated design were encountered during construction. Williams Brothers was awarded the construction contract for Phase 3 through the TxDOT standard low-bid process. One of the major change orders incurred on the project included a landfill encountered during construction, which resulted in approximately \$6.5 million of additional costs due to unforeseen conditions. Another major change was caused by misclassification of piping as a result of misidentifying soils. This could have been the result of the accelerated design process and may have been an aspect that

was rushed, thereby leading to a design error. A change order was granted to change the Class III pipe to Class IV and V in various locations for the cost of \$1.13 million.

Schedule

The NTTA board of directors approved a negotiated value for SH-161 with TxDOT in April 2008, ensuring that the road will be constructed as a toll road and giving TxDOT the go-ahead for construction. On October 15, 2008, the NTTA accepted a term sheet with TxDOT and exercised its SH-161 option to develop the corridor as a toll road. On February 18, 2009, the NTTA board approved a project agreement between NTTA and TxDOT that authorized the NTTA to design and build Phase 4. In August 2009, the board approved a contract with Prairie Link Constructors (PLC) for Phase 4. The project is scheduled for completion in 2012.

Technical

The major technical challenges faced in the planning process of SH-161 included the completion of the accelerated design in time for bid lettings and the organization of design. The accelerated design process may have contributed to the change orders and design changes that were necessary during construction (Phases 2 and 3). The design errors could have been the result of low quality, acceleration, or lack of coordination.

For Phase 4 of the project, which is currently in construction, NTTA awarded a design-build contract to PLC. PLC is a Fluor-led 60:40 joint venture with Balfour Beatty Infrastructure Inc. It includes the services of a number of firms that include AECOM (lead design), PSI (independent quality assurance and control), and Hicks and Company (independent environmental compliance). Phase 4 is scheduled to be completed in the fourth quarter of 2012,

and many of the issues regarding design and construction efficiency will be more clearly observed at that time.

Context

The context issues of this project were the greatest contributors to its complexity. They included multiple agencies and ownership, a variety of interested parties, political pressure, and location.

Multiple Agencies/Ownership

The project was a result of the collaboration and coordination between large entities. These include NTTA, TxDOT, and the Regional Transportation Council (RTC), which is the transportation planning entity for the North Central Council of Governments (1). FHWA was also involved in the project. In addition, the project passes through two municipalities: Irving and Grand Prairie. The Union Pacific Railroad will also have a railroad crossing over the main lanes.

Multiple Interested Parties

The project involved heavy public interest and pressure from parties involved with the opening of the new Dallas Cowboy's Stadium, the Texas Ranger's Stadium, and the Dallas/Fort Worth International Airport (DFW).

Location

Located along the western boundary of Dallas County in North Central Texas, the project was needed to sustain transportation in the high-growth center of the Dallas/Fort Worth Metroplex. It will play a role in the continuing growth of the overall region.

Many environmental concerns were faced in this project, which included a water feature, a railroad crossing, and a landfill encountered during construction. The West Fork Trinity River

crosses through the project as well as several smaller water channels that include Bear Creek, Johnson Creek, Cottonwood Creek, and Kirby Creek. These water bodies and other environmental concerns provided an extensive need, and requirements, for National Environmental Policy Act (NEPA) coordination and documentation. Environmental planning and permitting were executed in the development phases of the project and took years to complete. Because the Union Pacific Railroad crosses through the project, agreements were made with the railroad to construct a bridge during the final phase of construction after negotiation. The landfill encountered during construction added additional cost to the project as well as time to remove material in the fill and replace with select fill.

Financing

The estimated capital cost of Phase 4, the electronic toll system within Phases 2 and 3, and the railroad work is \$601.5 million (1). The project was also complex because of the nature of financing. TxDOT had already completed the frontage roads and ROW acquisition process for the project when the NTTA expressed interest in the conversion to a tollway for the planned construction. Therefore, an upfront payment of \$458 million was made to TxDOT from NTTA. NTTA applied for a Transportation Investment Generating Economic Recovery (TIGER TIFIA program to be allocated to no greater than \$40 million. The TIGER allocation will provide NTTA with the requested TIFIA loan of approximately \$393 million (1).

According to Bob Brown, the deputy district engineer for the TxDOT Dallas District, the \$20 million TIGER grant will be used to assist the funding of a TIFIA loan; the TIFIA will be part of the financial plan for the SH-161 project. NTTA must finance approximately \$1 billion, of which \$458 million is paid to TxDOT, with the rest of the money funding construction. NTTA will get

a TIFIA loan of about \$400 million and has sold about \$600 million in toll revenue bonds for the financial plan (3). Figure B.27 displays a breakdown of the financing for the NTTA portion of the project, which includes the upfront payment made to TxDOT as a result of the market valuation process to operate Phases 1–3.

Sources of Funds		
	Total \$	Total %
Revenue ¹	40,871,266	3.23%
Interest Earnings	-	0.00%
Senior Current Interest Bonds	454,325,555	35.93%
Subordinate TIFIA Loan	393,011,986	31.08%
Equity	376,254,576	29.76%
Total	1,264,463,383	100.00%

Uses of Funds		
	Total \$	Total %
Construction	601,469,953	47.57%
Upfront Payment (Includes Phase 2 & 3 Reimbursement)	458,000,000	36.22%
Capitalized Interest Fund	127,725,129	10.10%
Rate Stabilization Fund	37,269,483	2.95%
Major Maintenance Reserve Fund	4,080,033	0.32%
Operations and Maintenance ²	23,708,910	1.88%
Major Maintenance ²	1,229,652	0.10%
TIFIA Upfront and Ongoing Fees	1,165,338	0.09%
Other Transaction Fees	9,814,883	0.78%
Total	1,264,463,383	100.00%

(1) Revenue from the operations of Phases 2&3 during the construction period

(2) O&M and major maintenance costs for the operations of Phases 2&3 during the construction period

Source: Model v022d - TIFIA Application with NTTA revenue and cost inputs v16

Figures are preliminary estimates and subject to change based on market conditions and further diligence by NTTA and TxDOT

Figure B.27. TIGER TIFIA loan application (provided by NTTA).

Project Execution

Phases 1 and 2 are complete and open to the public. Phase 3 has reached substantial completion.

Phase 4 is in the execution stage and is scheduled for completion in 2012.

Cost

Williams Brothers was able to self-perform a large amount of work of the Phase 2 construction and so were able to save substantial amounts of cost on items such as drill shafts. Williams Brothers was also a low bidder for the contract. Although the low-bid process does not always result in the selection of the most qualified contractor or highest quality, in the case of Williams Brothers TxDOT was satisfied with their performance. In addition to self-performing items, Williams Brothers was able to work 24/7 when necessary to accomplish milestones on schedule, which worked in favor of all parties. The project was completed on time, and the contractor received a substantial incentive payment for completing ahead of schedule.

The capital cost of the project so far is estimated to be around \$600 million. Phase 2, which consists of two main lanes in each direction from SH-183 to Egyptian Way, is an example of the methods of cost control used for the project.

Schedule

The schedule of construction was crucial to the project. It is vitally important that the phases of the project be opened on time. Therefore, incentives and disincentives and liquidated damages were a part of the construction contract. Williams Brothers, the contractor responsible for Phase 2 construction, met the schedule for Phase 2 through 24/7 work when necessary and self-performed work that included drill shafts for structures. The contractor was able to complete the work ahead of schedule and was awarded a substantial incentive payment.

Construction of Phase 1 is open to traffic. On August 2, 2009, two main lanes in each direction within Phase 2 opened to traffic while the remainder of the work was completed to meet the demands of the Dallas Cowboys' Stadium opening. Phase 2 elements are expected to be

completed by January 2011. Phase 3 roadway elements have been designed and are under construction by TxDOT.

Technical

One difficulty presented during the construction of the project was that numerous inspection and testing entities were involved. There was a mixture of TxDOT employees and various consultants hired to inspect the project and perform testing. This variety posed a difficulty for the contractor, especially in addressing inspections and testing, quality control, and questions arising from construction documents.

As stated above, the execution of construction as a result of the low-bid process could have been a threat had a contractor been awarded the project and then had been unable to meet the level of performance, multiple resources, and quality required by this project. It was fortunate that Williams Brothers was the low bidder and that issues that arose during construction were able to be resolved.

Context

All of the context issues presented in the planning and procurement phase were, and continue to be, relevant in the project's execution. Coordination with multiple entities, including the public, the sports mecca, municipalities, and all other interested parties, on the part of the contractor, NTTA, TxDOT, and FHWA remains a vital part of the project's success.

Financing

The financing was a large contributor to the complexity of this project and was discussed in detail in the planning and procurement phase summary. The NTTA will finance the Phase 4 design and construction with the assistance of a TIGER TIFIA loan as well as toll revenue bonds. The estimated cost of Phase 4 is around \$500 million.

Project Operation Phase

The operation of SH-161 will open in phases as the construction of each phase is completed.

Summary

This project was complex because of the magnitude, multiple sources of financing, context (political influences), accelerated scheduling requirements, environmental concerns, and railroad involvement. The planning and execution of SH-161 was successful because of the consistent collaboration among the entities involved. In the development sector, the FHWA, TxDOT, NTTA, and local governments were able to meet agreements that allowed for the acceleration of the design and construction to make the project a possibility years before it would have otherwise been completed. In addition, the interest in the project from the public, municipalities, railroad company (UPRR), DFW Airport and the sports sector (Texas Rangers and Dallas Cowboys) all created a unique dynamic for the project of vested interest in being informed through to completion.

Observations Made by the Researcher

The Texas SH 161 project was a perfect fit for a complex-project case study. It is a megaproject (\$1.2 billion) and has used a diverse mix of innovative technologies; multiple delivery systems; multiple agencies in charge of planning, design, construction, and operations; numerous funding

sources; multiple municipal jurisdictions; innovative financing; political, developmental, and social pressures; several important milestones with large incentives and disincentives; pavement, bridge, and interchange work involving two Interstate highways; hazardous material; landfill; flood plain issues; a railroad yard and contaminated water; tolled main lanes; and nontolled frontage roads.

However, even with all of these issues, the milestones are being met, and the entire project is on schedule to be completed on time. The participating agencies, entities, consultants, and contractors have found a way to overcome complex issues by collaboration, cooperation, and in some cases, sheer will power.

The most difficult part of this case study was to provide a comprehensive description that incorporated the intricacies of the project in a clear, concise format. The intention was to capture the complexity of the project without confusing the reader.

The most important lesson learned is that—with the proper incentives, tools, and experienced, dedicated individuals at agencies, as well as consultants, and contractors—quality transportation infrastructure can be designed and built within very strict time frames.

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Interviews

Tracey Friggle, Director of Construction, TxDOT Dallas District. Interviewed May 20, 2010.

Kathy Henderson. Recordkeeper/Inspector, KBR. Interviewed May 20, 2010.

Bill Doreen. Project Superintendent/Estimator, Williams Brothers Construction Co. Interviewed May 21, 2010.

Bob Brown, DFW Deputy District Engineer/DFW CDA Program Manager/Innovative Financed Projects. TxDOT Dallas District. Interviewed May 21, 2010, and July 1, 2010.

David Seago, Assistant Director of Construction, TxDOT Dallas District. Interviewed May 20, 2010.

T-REX Denver, Colorado

Introduction

The Transportation Expansion Project (T-REX) in Metro Denver, Colorado, consists of 17 miles of highway expansion and improvements to I-25 from Logan Street in Denver to Lincoln Avenue in Douglas County and improvements to I-225 from Parker Road in Aurora to a newly configured I-25/I-225 interchange, as well as 19 miles of light rail developments along these routes (2). Figure B.28 shows the project plan. The design-build project delivery was selected because of its ability to reduce the schedule and assign a single point of responsibility.

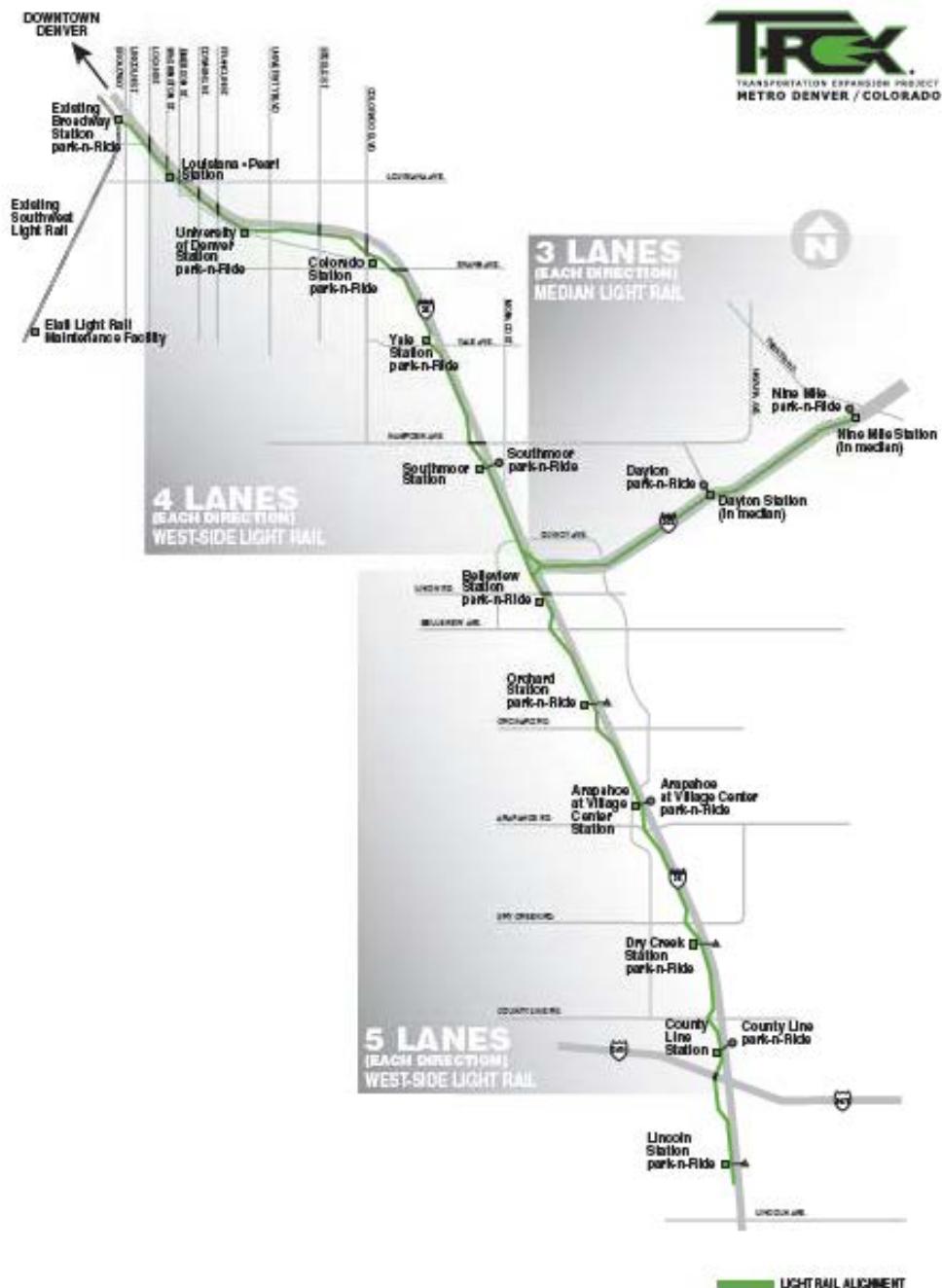


Figure B.28. T-REX project map.

Project Planning and Procurement Phase

Action Taken	Date
Environmental Impact Statement (EIS) announced when the Colorado Department of Transportation (CDOT) and the Regional Transportation District (RTD) signed an intergovernmental agreement to design and build a corridor together	1998
Request for Qualifications	April 2000
Three proposers short-listed based on financial ability; issued Request for Proposal	June 2000
Southeast Corridor Constructors (SECC), a joint venture between Kiewit Construction Company and Parsons Transportation Group	June 2001

Cost

The original cost for the project was \$1.67 billion. This included

- Design-build contract: \$1.2 billion,
- Maintenance facility: \$40–\$50 million,

- Siemens light rail vehicles: \$100 million, and
- ROW and administration: \$100 million.

This cost included 4% separate contingencies for highway and transit. One of the main aspects that made T-REX complex was that every dollar had to be tracked to determine whether it was highway or transit. Cost splits between highway and transit on items such as bridges were complicated because of the need for documentation to justify the split.

Schedule

The original schedule developed by CDOT for completion of the project was to finish the project on June 30, 2008. Proposers developed their own schedule. The SECC proposed to complete the project in the fall of 2006, almost 2 years ahead of the schedule developed by the owner.

Technical

CDOT and RTD took some proactive steps to ensure that the project was successful. They hired a consultant to help with contract formation and risk analyses. They also formed a dispute resolution board and formal partnering that were incorporated into the contract.

Context

The primary context issue that CDOT and RTD focused on in this project was to reduce inconvenience to the public. Other context issues that CDOT and RTD focused on were legislative changes to allow design-build and best-value selection in the state of Colorado, public outreach, utilities, and ROW.

Reduce Inconvenience to the Public

CDOT and RTD established early during the planning phase that the Number 1 goal was to reduce inconvenience to the public. It was determined that for the project to be a success in the public's eyes, completing the project on time and on budget was not enough. Because of the lack of alternative travel routes between downtown Denver and the southeast business district and the expected duration of the project, keeping the public content was essential.

Design-Build and Best-Value Selection

To accelerate the project and reduce inconvenience to the public, the traditional design-bid-build approach was not a viable project delivery method for T-REX. The then-governor had to sign legislation to allow design-build and best-value selection in the state of Colorado. T-REX was the first design-build project in Colorado and the first transportation project to cost more than \$1 billion in the United States.

Public Outreach

During the planning phase of the project, a marketing consultant was hired to develop an aggressive marketing campaign. The original name of the project, Southeast Corridor Project, was changed to T-REX to increase name recognition. The project's public involvement program included four rounds of open houses as well as the opportunity to participate in the environmental planning process (2).

Utilities

Since T-REX was an expansion to an old urban corridor, existing utilities were one of the biggest risks in the project. CDOT and RTD worked with 45 utility companies that were responsible for more than 800 separate utilities to develop agreements before the procurement phase. Utility

companies and qualified contractors completed \$2.5 million dollars of utility relocation work before the contractor received notice to proceed (2). Identifying existing utilities and relocating them early in the project provided less risk to the contractor.

Right-of-Way

The widening of the highway and construction of the light rail transit required some ROW purchases. Relocation experts worked one on one with homeowners and tenants. They explained homeowner and tenant rights and provided help with financing and locating replacement housing. Relocation benefits included home-buying assistance, money to supplement rent, and moving costs. The T-REX project required 30 total acquisitions and 172 partial acquisitions (2).

Financing

This is a public project financed by two federal sources (FTA and FHWA), CDOT, RTD, and local agencies. Voters had to approve House Bill 1325 (TRANS) to enable issuing transportation revenue anticipation notes.

Project Execution

The T-REX groundbreaking ceremony took place on September 24, 2001. SECC completed construction on September 1, 2006 (2).

Cost

Since this was a design-build lump-sum contract, the contractor was at risk for cost fluctuations. CDOT and RTD had a fuel adjustment factor clause and had to pay more than \$1 million to the contractor.

Schedule

The project was completed according to schedule. Some concrete shortages occurred during construction, but they did not really affect the project. Suppliers limited concrete quantities to smaller clients in the Metro Denver area.

Technical

The technical issues that CDOT and RTD focused on were global and national incidents, quality assurance and quality control (QA/QC), and aesthetics.

Global and National Incidents

T-REX was awarded, and SECC was given notice to proceed before the unfortunate event of 9/11. After this event, the project experienced increased labor availability and reduced inflation during the execution phase.

QA/QC

According to Larry Warner, the CDOT T-REX project manager, the QA/QC were assigned to the contractor, but all of the owner's staff were trained to conduct quality audits. Warner stated the importance of trusting the contractor because CDOT did not have the resources to maintain continuous supervision. Warner gave a couple of examples of times when the quality of a specific portion of work met CDOT's criteria but the contractor decided to redo the work because it was not satisfied.

Aesthetics

RTD had a commissioned art program that allowed community members to participate in the selection of art for their light rail stations. In addition, there were three canopy styles to choose from (2).

Context

The main context issues that CDOT and RTD focused on were public outreach and public emergency services.

Public Outreach

During the construction phase, T-REX was in the news daily, with both the owner and contractor speaking to the media as “one voice” (1). This extensive and sophisticated outreach allowed the public to see progress, and it avoided many of the common public complaints, because people like seeing progress and how public funds are being spent. The contractor maintained a website that contained a real-time map showing traffic conditions, closures, actual travel time, and so on. Hotel vouchers were given to residents who experienced excessive noise at night from construction.

Public Emergency Services

Because of the lack of alternative travel routes and night closures of the highway, CDOT created an emergency services task force, which helped to develop an emergency procedures manual. CDOT informed emergency services of closures and detours.

Financing

As discussed in the planning stage, T-REX was a multimodal project financed by two federal sources (FTA and FHWA), CDOT, RTD and local agencies. There were many restrictions on how the money allocated was used. Cost splits between highway and traffic were complex.

Conclusion

After meeting with the CDOT T-REX project director, Larry Warner, it was concluded that the factors that contributed to the success of this complex project are the following:

1. *Minimization of inconvenience to the public.* The primary goal of the project was to minimize inconvenience to the public by maintaining traffic capacity during construction and reducing the project duration. It was determined that for the project to be a success in the public's eyes, completing the project on time and on budget was not enough.
2. *Design-build project delivery.* This method allowed the project to be completed on a reduced schedule, which was important because of the lack of alternative travel routes.
3. *Staff selection.* The owner was able to handpick its internal team.
4. *Public outreach.* The project had an aggressive marketing campaign. The brand "T-REX" was introduced and was in the news daily. The contractor maintained a website that contained a real-time map showing traffic conditions, closures, actual travel time, and so on.
5. *Utility agreements.* Since T-REX was an expansion to an old urban corridor, existing utilities were one of the biggest risks in the project. CDOT and RTD worked to develop agreements with utility companies before the procurement phase. Identifying existing utilities and relocating them early provided less risk to the contractor.

Observations of the Researcher

Greatest Challenges

- Challenging work environment due to need to keep highway open during the construction;
- Tracking of funding (highway vs. traffic dollars); and
- Bipartisan support because political parties did not want to lose elections if T-REX failed.

Successful Accomplishments

- Good partnering between owner and contractor: trust, colocation of staff, decisions taken at the lowest possible level;
- Zero claims;
- Constrained budget at the start allowing scope to be consistent;
- Very disciplined project management;
- Public outreach: contractor and owner speaking to the media as “one voice”; and
- In-depth project planning phase
 - Contract consultant,
 - Marketing consultant,
 - Utility agreements, and
 - Early solution of many potential problems.

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Capital Beltway

Introduction

The Capital Beltway project in northern Virginia is a complex project currently in the construction phase. It consists of four high-occupancy vehicle (HOV)/high-occupancy toll (HOT) lanes of 14 miles, lane connections, construction or reconstruction of 11 interchanges, and replacement of or improvements on more than 50 bridges. The total awarded value of the project for construction and administration is \$1.4 billion. When financing and design are included, the total awarded value of the project reaches \$2.2–\$2.4 billion. Planning of the project began in 2003. One interesting fact about this project is that an unsolicited proposal was issued in 2004, and the owner negotiated under public–private partnership (PPP). Actual construction began in July 2008 and is scheduled to be completed in 2013. Tolling and revenues are expected to start on December 21, 2012.

Innovative financing (PPP) was the single most-significant reason for the delivery method decision along with acceleration of project delivery period, innovation encouragement, risk redistribution, and follow-on operations and maintenance.

Project Planning and Procurement

Cost Complexity

Cost risk analysis was more complex than typical projects and a source of complexity. To measure cost risk, the owner arranged for a series of independent estimates and a series of risk analyses as to how likely risks would happen, what the risks were in the specifications, and how much they would cost. Managing the gaps between different sources of funding was another complex task for the cost risk analysis.

Transit and revenue studies had to be incorporated into the estimates so that the Virginia DOT (VDOT) knew before entering negotiations how much revenue the project would likely take in once in operation.

Owner resource cost allocation was a source of complexity. The owner experienced large budget cuts during the process and underestimated the costs of internal resources.

Cost control was challenging to VDOT in that VDOT was an independent verifier and had a very limited role as the contract was being written. VDOT was not adapted to this role. From the standpoint of communications and public outreach, VDOT and the developer are the same, and each had a tendency to increase its oversight role. But the developer was not growing in its role of oversight, so the budgets for each party did not match the associated roles and responsibilities.

Effective Tools for Managing Cost Complexity

Transferring risk to the developer by using PPP was used as a tool for managing cost risk, which cost the owner more money.

Schedule Complexity

One source of schedule complexity is that so many different parties were involved, such as a concessionaire, the federal government, the state, and the developer. All parties involved were interested in the outcome of the schedule.

A high focus on the schedule risks affected the project cost. Formal and informal risk analyses were executed, and the effect of ROW and utilities was analyzed.

Effective Tools for Managing Schedule Complexity

VDOT provided assistance to alleviate schedule risks with ROW acquisition, which was not VDOT's responsibility. A scheduling system and software, P6 (resource- and cost-loaded), was used. Bringing schedule teams together in the planning phase made it easy for the project participants to determine a transparent and agreeable schedule.

Technical Complexity

Defining project scope was not an easy task for this project. There was scope creep, and the scope had to be cut back. Because of trade-offs between the parties (developer, owner, etc.), reducing the scope was a difficult process.

Getting the authority to establish the organization and getting decisions made by the chief engineer (commissioner) was more complex than on normal projects because of the size of the project, even though VDOT has had much experience with megaprojects.

The Capital Beltway project was delivered by PPP with DB. The VDOT megaproject team had previous experience with the DB approach, but still had some unfamiliarity with it. This unfamiliarity made the project delivery method more complex than a normal project.

As previously mentioned, because of the unfamiliarity of the delivery method and contract type, VDOT staff believed that contract formation was more complex. Issues relating to contract formation included defining the responsibilities of each party and developing specifications.

As the contract was written, VDOT was an independent verifier and had a very limited role in construction quality, as mentioned earlier in the discussion on cost control. VDOT had difficulty adapting to this role.

Developing the HOT network and switchable hardware to accommodate HOT and HOV users was a very challenging task for intelligent transportation systems (ITS). There were many technical factors for developing the HOT and HOV lanes to consider, such as choosing pass type (electronic pass or not, or both), determining how to recognize the number of people in the vehicles and how to distinguish animals or stuffed dummies from human passengers, and many other issues. Besides these technical matters, laws also had to be considered to make sure the developed system is not illegal. For example, whether photos can be taken for toll enforcement should be determined before application.

Effective Tools for Managing Technical Complexity

Several tools were applied for the owner's internal structure. VDOT used a highly transparent structure, a single point of responsibility, past projects' experience, and decentralization of

project control. VDOT had an integrated project delivery team to get involved early and determine resources.

Context Complexity

Because the project location is in the metropolitan Washington, D.C., area, high stakeholder involvement was anticipated. There were at least 100 groups to manage, as well as a knowledgeable public, so it was impossible to cover up any information. Everyone involved was concerned with some aspect of the project, so VDOT had to prove the benefit of the project to the public. In addition, everyone involved was politically connected, so VDOT needed to know who was talking to whom in meetings. Even for very local issues, supervisors had to respond to their constituents in order to get reelected. Sound walls are a good example of an issue that was very politically generated. The change in administration that occurred every 4 years was also a complex issue. VDOT also had to deal with powerful jurisdictions in the metropolitan D.C. area. The county staff that VDOT dealt with outnumbered VDOT's megaproject staff for the project. Many of the advisory committees demanded numerous answers.

Maintaining capacity, especially for traffic control plans, was a source of complexity. The Capital Beltway project affected major routes in the metropolitan D.C. area, and as a result, no roadway was unaffected by the project.

VDOT underestimated disadvantaged business enterprise (DBE) and civil rights participation initially, and then realized that when dealing with a business, the project affects multiple parties (business owner, landlord, customer, etc.) and the surrounding communities.

Construction projects in urban areas often bring fierce competition between the media for stories. It was a challenge to market a toll lane (also called the Lexus lane), which was new to the

area. VDOT had to not only do the marketing but also provide education on the new concept of a toll-based lane.

Utility coordination was very complex because of many types of utilities, which were a combination of new and old utilities as well as security utilities.

Local acceptance and procedural law for the acquisition process were complexity sources. Project information was owned by the developer, so the public initially felt left out. Concerns over access connections to the Capital Beltway made airport authorities look closely at the permitting and land acquisition process.

Effective Tools for Managing Context Complexity

Communications and outreach plans were developed and maintained 24/7 with a public communication line. When VDOT said 24/7, it guaranteed a response right away at any time of the day in response to the market and the expectations of VDOT. To build positive relations with the local community, VDOT sponsored and supported many civic events to help ensure trust. VDOT's public information team was one of the largest in the state. Communicating and fulfilling promises were the tools VDOT used to answer politicians' requests. A straight line to the secretary was provided to move things along and manage information for the sake of the extensive political involvement. From the owner's point of view, decision making from lower personnel for matters normally made at a much higher level served very well as an effective tool. More authority was given to lower levels of personnel to manage this megaproject.

To maintain traffic capacity, network modeling for contract parameters was executed, and the impact of changes was analyzed. Traffic control plans and maintenance of traffic plans

were further refined during the design and construction phase. Previous projects' specifications were imported for reference.

Additional personnel in the VDOT project team were designated to facilitate the ROW process for land acquisition. Once parcels reached condemnation, VDOT's ROW project manager (PM) was in charge.

For local economics and marketing purposes, several tools were used. VDOT worked to keep everyone informed through newspaper (project specific), website, radio, and advertisements. Text messages were sent out in multiple languages to make sure more people got important information. The marketing plan prepared by the developer was a requirement by VDOT. VDOT required the contractor to maintain access to businesses, which ensured the local businesses that VDOT was really listening to their concerns. VDOT also tried to go out and talk to businesses well ahead of time because the longer the lead time, the better.

Financing Complexity

The legislative process for the public–private transportation act was complex. The concession-funded project legislation required the private partner to provide funds (\$6 million for VDOT development costs and \$15 million for traffic enhancements) in the project development phase; the private partner would generate revenue from the tolls later. Limitations posed by the various funding sources caused some issues. On the basis of general assembly appropriations language, if money is not received from the private partner, then VDOT cannot make the payment.

Instead of providing training to the project manager in financial management, VDOT decided to assign a financial expert because of the project's size. A total of \$409 million was a federal–state match, \$157 million of which was obtained from the Transportation Infrastructure

Finance and Innovation Act (TIFIA). The private partner applied for TIFIA. VDOT got involved in the process and showed its support for the project.

The legislative process for the bonds was not complex. When VDOT decided to use private activity bonds, the Virginia small business authority gave permission to sell them, although at the time, there was no statute to sell bonds for transportation.

Global participation was available for this project. Transurban (private partner) is based in Australia, with a social purpose vehicle called Capital Beltway Express, LLC. Transurban participated through an unsolicited proposal and accepted much personal risk.

Effective Tools for Managing Financing Complexity

An independent financing team was in charge of developing funding sources. This team worked with an innovative project delivery group, which focuses on the technical aspects, while the financing team takes on a consulting role for financing issues.

VDOT set up a nonprofit to sell the bonds, thereby putting liability onto the private partner. VDOT had to update legislation so as to sell bonds for transportation purposes.

Project Execution Phase

Cost Complexity

The owner initially assumed that contingency would not be a line item. However, potential scope changes added special contingency funded by the state legislatures later. The owner experienced difficulty determining the contingency at the outset.

Effective Tools for Managing Cost Complexity

No specific tools were used for contingency. After execution, the project team looked at weaknesses and anticipated scope changes, then developed a contingency plan. Contingency ended up being 10% of the total project and had a heavy impact on the final project.

Even though incentive usage was not a source of complexity to the VDOT personnel, an interesting tool was used to accelerate the project. VDOT and the developer used value engineering to compress the schedule for specific critical connections.

Schedule Complexity

Same as planning phase.

Effective Tools for Managing Schedule Complexity

Same as design phase.

Technical Complexity

Many issues arose over dispute resolution during the execution phase. In the negotiation process, bad feelings built up between the involved parties, which led to bad relationships. While representatives of one of the Washington, D.C., airports wanted to address their issues, which could have held up the project, the developer had project-permitting responsibility. Therefore, ambiguous contract language caused disputes between parties.

The design method was a source of technical complexity. The project management team had to work with designers from two different parties, namely, the owner and the developer. There were many design packages to get through in a timely manner. VDOT examined 200

design packages in 18 months. VDOT could not ask for too much in the design process because of authority and cost matters. Therefore, the focus of review and analysis was on finding balances between parties and between cost and schedule resources.

Effective Tools for Managing Technical Complexity

People at the highest levels reevaluated negotiations. The dispute resolution process was included in the contract. Development of working relationships, a “lockdown” to finalize disputes, and development of levels of resolution for each of the issues were the tools for dispute resolution.

Context Complexity

Same as planning phase.

Effective Tools for Managing Context Complexity

Same as planning phase.

Financing Complexity

Same as planning phase.

Effective Tools for Managing Financing Complexity

Same as planning phase.

Ohio River Bridges

Introduction

The Ohio River Bridges project in Louisville, Kentucky, and southern Indiana is a complex project currently entering the final stages of the design phase. It consists of two long-span river crossings across the Ohio River (one in the downtown location, one on the east side of the metro), a new downtown interchange in Louisville, a new approach and a 4.2-mile-long highway on the Indiana side, a new East End approach on the Kentucky side that includes a 2,000-foot-long tunnel, and reconfiguration of existing interchanges to improve congestion, mobility, and safety.

Project Planning Phase

The Ohio River Bridges project has been in development for many years. Formal analysis of cost/benefit began in the mid-1990s. The draft EIS was submitted in November 2001 analyzing nine alternative bridge locations in one- and two-bridge combinations. The final EIS was issued in April 2003 with a preferred alternative for bridge location and alignment and a plan for mitigating impact on historic properties and neighborhoods. The Record of Decision was issued in September 2003, with requirements for continuing community involvement during design and construction to ensure compliance with requirements. The EIS process was completed in 5 years.

Much more complicated than the EIS was the Section 4(f)-106 process. This process was begun before the Record of Decision and had to be managed simultaneously. The 4(f)-106 memorandum of agreement (MOA) contained 52 pages of project commitments. These commitments were made to mitigate impact and to allow the project to move into the design

phase. Advisory Council on Historic Preservation (AChP) sign-off was critical to advancing the project scope, as originally defined in the planning stage. FHWA authorized the project in 2003. However, shortly after authorization and commencement of design, the revised construction cost estimates came in at \$4.1 billion, approximately \$2 billion dollars over previous estimates. This “sticker shock” caused the construction phase of the project to be placed on hold. Design has continued to near 100% completion, and ROW acquisition and utility relocation and coordination have continued as well. A bstate authority has been developed and charged with identifying financing and funding options to pay for the increased cost of the project. The commission’s report and recommendations are due at the end of the year (December 2010). Construction and procurement phases cannot begin until a feasible financial plan and funding sources have been clearly articulated.

Sources of Complexity

Cost Summary

The project has been in the planning stage for several years. There was an option to rebuild or rehabilitate existing bridges, roadways, and interchanges in the mid-1990s. The project team did a complete analysis that included travel times, user benefits, and comparison of alternatives. The team decided to rebuild some of the project under traffic, add a new bridge and some new approach work, and realign the interchanges. There is an estimated \$2 billion benefit over 10 years. A bstate authority has been established that will model cash flows on the project. Kentucky has changed to a pay-as-you-go state, and Indiana has cash available from monetization of its toll roads. Availability of labor and material supply regionally, along with

cost and bonding issues, will limit the number of bidders on the project. Because of the size of the project, it is likely there will be some type of consortium to complete the project.

The project team looked at project insurance to offset the cost of bond financing, but it was determined not to be practical. Bonding agencies have expressed some concerns because of the scope and size of the project. The bistate authority is taking this issue into consideration as part of its financing recommendations. A thorough risk analysis was completed by using the Monte Carlo method for each stage and segment of the project and then aggregating for the entire project. The risk assessment was completed in 2007 per FHWA recommendations for major projects.

Preliminary engineering from the EIS process was used to create a conceptual cost estimate. As of 2007 and early 2008, traditional funding was anticipated, but cost escalated quickly, and the Kentucky legislature was concerned that the project would consume 60% of state program money each year for several years.

Primavera software and earned value analysis were used to track cost and coordinate the work. The project team leaders had to train consultants on how to use these tools and good progress was made on using a uniform planning software and cost management system. However, as the project has lingered and been put on hold, these cost management tools have become less useful and unmanageable. Change management has become a bigger problem and has added complexity to planning and cost control. Unallocated fund transfers have been made to keep the project moving. The Kentucky DBE mentoring program provides training in Primavera and the earned value management system (EVMS). Project delays have hampered the effort to retain DBEs. All DBEs will be prequalified before construction. The mentoring program has

added to the qualified local workforce, but project delays have caused problems in keeping trained people involved.

The biggest problem is the total project cost. A very large project scope and scale has created the need for innovative financing. A bistate group will review cost and financing and funding recommendations by the end of the year. Legislation from both states will be required to approve a financing plan if it involves something other than traditional programmatic funding tools.

Effective Tools for Managing Cost Complexity

The project team reported that Primavera software, EVMS, and DBE mentoring program on cost control and planning were effective, but the cost escalation has reduced the effectiveness of many of the cost management tools. Risk analysis was thorough and in depth but came after a commitment to alignment and project scope was firmly established. The project scope and alignment were determined in late 2003, and the formal risk analysis was not completed until 2007.

Schedule Summary

The project schedule was very tight near the end of planning and at initiation of the design phase, but then the project was put on hold when sticker shock hit. The project structure, organization, and delivery were determined by legislation, but these factors may change on the basis of recommendations in the bistate authority report on financing. Design and ROW acquisition have continued while financing issues are being worked out. Continuing inflation may make the project unaffordable.

Schedule was a top priority until the project was put on hold in 2008. The specifications required a CPM schedule from all consultants and contractors. The most common program used was Primavera. Project draw schedule (cash flow) affected section design and the phasing plan. Primavera was used early in the project for planning and design activities. Work breakdown structure and resource-loaded schedules were used in design and were linked to payment applications from consultants. The biggest schedule problem is that the revised (\$4.1 billion) estimate slowed down the project because of insufficient funds.

There are some schedule constraints that will affect construction. A wellhead protection system will need to be in place before construction can begin. Pretreatment tunnels near the river need to be protected; this is an absolute (constraint) that reduces the ability to optimize schedule. Many utilities in downtown Louisville have poor records (as-builts) on size, type, and location. A major transmission line in the realignment corridor will have to be moved before construction can begin, and this will take a year. The East End alignment requires blasting near old 60-inch water mains that are of uncertain integrity. Many unknowns and constraints, particularly with utilities, make it difficult to plan and optimize the schedule.

The project team used Google maps to visualize and communicate routes, phasing, and bridge openings to the public and among project team members. Project leaders and section design leaders were responsible for creating and coordinating the work. They used frequent, face-to-face meetings to supplement EVMS and resource-loaded CPM plans

The crash rate in the area near the existing downtown bridge is 2.4 times the national average. Congestion in downtown Louisville is the 11th worst in the country. This situation will get worse and safety will be compromised until the new project is completed, so schedule delays

have a real economic and human impact. Kentucky is using GARVEE bonds to move forward with ROW purchase on the Kentucky side.

Logical, practical, and reproducible baseline documentation was critical to EIS and the 4(f) process but was time-consuming. The Section 106 process was in place before the Record of Decision; these must be done in parallel to keep the schedule on track. The Section 106 process turned out to be enormous with 52 pages of commitments in the MOA consistent with impacts. The EIS process was completed in 5 years, which is relatively quick for a project of this scale. The EIS process was well managed because of good baseline documentation.

Many commitments were made to mitigate impacts to keep the project moving along and get the design phase under way. ACHP sign-off was critical because Section 4(f) requirements have “more teeth” in terms of compliance. The project team had to work out a deal with the help of FHWA to get the project moving forward.

Effective Tools for Managing Schedule Complexity

The project team had good success with Primavera and resource-loaded CPM schedules in managing the schedule. Thorough preparation and background documentation for EIS and 4(f) processes were critical, and managing them simultaneously was useful in keeping the project moving forward.

Technical Summary

The scope of the project has negatively affected procurement and construction.

The project is currently managed as part of the regular program in Kentucky and Indiana, which is probably not feasible for construction (too expensive). The final organizational structure

for the project will depend on financing. Contractors will need to prequalify once the project moves to the construction procurement phase. The dispute process as established in the MOA has been working well, but groups not signatory to the MOA (i.e., River Fields) are not bound by the dispute resolution process. The dispute processes to be used in the construction phase are still to be determined, although currently the standard specifications for each state are anticipated for construction dispute language. Delivery method and construction contracting will be largely determined by the financing solutions. The design method and organizational structure for the planning and design phase were dictated by legislation, which stipulated that a general engineering consultant (GEC) be used. CTS, a joint venture between BLN and Parsons, designed and reviewed the Kennedy interchange segment and coordinated with each segment leader for the other segments of the project. Existing conditions, especially utilities, caused substantial technical complexity.

Safety factors included separating bike paths from the major corridor. Another technical factor associated with location and geography includes flood walls. Some new technology was involved in the preliminary tunnel design. ITS have been built into every segment and will be expanded in the existing corridor. The systems will be privately managed and operated. The GEC also retained consultants for ROW, utility, and some technical specialties (i.e., tunneling, bridge lighting).

Any use of warranties will be dictated by financing and procurement recommendations. Design development was a public process for signatories to the Section 106 MOA. Several stakeholders are involved in design reviews. FHWA works closely with the SHPO.

Any innovative contracting will be dictated by financing decisions. It is likely the project will use some performance specifications (i.e., ridability, densities). Value engineering was

performed by design teams on five of the six segments, but no constructability reviews were included. The industrial ports along the river posed a technical challenge because the project phasing must maintain access for trucks. Additional technical challenges include six lanes of deck rehabilitation under traffic on the existing bridge. Last, the height restrictions on the main span bridge towers and the span requirements for extensive barge traffic created technical complexity. Flooding is always an issue in the area, and there are zero rise constraints that affected bridge geometry. 3-D models built with Microstation and 3D Max were helpful in communicating and visualizing potential solutions. ProjectWise Digital Architecture was used for the bridge, and each section's designers also used their programs for design. In addition, the use of Google maps to link all project segments and present the project to the public was valuable. Ground-penetrating radar was used to confirm subsurface conditions. An innovative concept near the industrial ports involves the use of diverging diamond interchanges, which eliminates the need for signalized intersections and maintains traffic flow in a section of road with a high percentage volume of trucks. Horizontal drilling will be used for the tunnel sections, which will result in the widest tunnels in America.

Controlling expectations requires everyone to speak with one voice. CTS speaks on behalf of both states on what should be or can be included in the scope of the project.

Cost implications were used to manage expectations, but there may have been a problem with scope control and change management. The final project includes 82 bridges, 20 miles of ramps, and 4 miles of retaining walls at the Kennedy interchange. It will eliminate weaves at the I-64/I-65/I-71 bridge interchange, will be aesthetically pleasing, and will preserve historic neighborhoods. This may have been too big a scope to effectively manage. Massive project

scope and the complex 4(f) process affected the ability to design to a budget. Construction inflation increased project cost dramatically near the end of the design phase.

Effective Tools for Managing Technical Complexity

The project team reported that use of Google Maps and other 3-D visualization software helped communicate the project scope to the public, the media, and to internal team members. The 4(f) process resulted in scope increases that made it difficult to control costs. Use of a GEC to provide multijurisdictional coordination and serve as a single point of contact was effective.

Context Summary

A smart growth conference was required per the Section 106 MOA. The conference was required to be held within 3 years of the Record of Decision to create awareness and some coordination between area planning agencies. The smart growth conference was an excellent mechanism for starting an areawide dialogue on the project. Significant public involvement was also required in the MOA. Many commitments were made to try to keep the project moving along and to overcome opposition. These commitments led to cost escalation and scope creep.

Metro governments and local agencies and most politicians accept the project plan and the process used in the planning process. However, financing the project has become political, and many jurisdictions are involved in the project.

CTS oversight on design was dictated by legislation. CTS used video- and teleconferences as well as frequent face-to-face meetings to coordinate the planning and design of the project. Section design leads were assigned to each of the six sections, with CTS coordinating and managing the interface. Traffic control plans were developed with section designers responsible for phasing of traffic control while CTS provided “big picture” oversight.

Once under construction, traffic control will use message boards. Specifications are complete for these message boards.

The project is not considered multimodal, although there were issues of access and capacity coordination with port facilities on the Ohio River and a commitment to increased bus service.

Many issues were related to historic preservation, with plans submitted to each city, village, neighborhood group, and so on. The project will result in more public land use: converting old industrial areas to the new interchange and reverting old interchange land to public parks. A public relations and communication consultant has been valuable and will be retained during construction. The intention is to use the public involvement consultant to help coordinate information during the construction phase and to serve as a primary point of contact for the media and public at large.

The project prompted some long-term land use planning by local agencies. Extensive analysis during the EIS process helped with corridor-level planning decisions. The economic impact of the project was obvious, but planners stayed with conservative regional planning projections to reduce the opposition's ability to criticize the numbers. A decision was made to use a tunnel for historic preservation of a Frederick Law Olmsted country estate design and mitigate 4-(f) issues in that area of the project. Alternative solutions would have required relocation of the corridor alignment.

Environmental issues were not as significant as the social and historical preservation issues. Some endangered species were found in the corridor, but none of them severely affected design. Water must be contained on the bridge and within the wellhead protection zone, which created some design complexity. The tunnel project also had environmental limitations.

In general, the project has a positive rating in the community, with 76% of the public at large supporting the project. There is widespread understanding of the need for the project. However, some “old school” attitudes have opposed the project, and they are politically powerful. The River Fields neighborhood preservation group strongly opposes the project.

Climatic conditions are manageable, although the project does have a contingency for potential flooding along the river.

Effective Tools for Managing Context

Historic preservation teams give credibility to the project and help overcome some of the political opposition from the East End. The state historical preservation officer and local groups meet with the project team every month.

The public relations and communication consultant has been valuable in coordinating information and providing a point of contact for the public and the media.

The smart growth conference was an asset to the project. However, there is a potential for unintended consequences (project leaders may not get the answers they want, but the conference is a valuable means for starting a dialogue).

Financing Summary

The expanded project scope and cost increase caused by inflation in 2003 make traditional financing unworkable. Revenue generation options were discussed in planning, but tolls were dismissed. Revenue generation was discussed in the FHWA financing plan, but bonds and revenue were deemed unnecessary on the basis of the original cost estimate. However, both of those options are back on the table now that the design phase is wrapping up, and new cost estimates place project cost at more than \$4 billion. If tolling is pursued, electronic tolling is the

only option because there is no budget for traditional tolling infrastructure (booths, stopping lanes, and so forth). Vehicle mileage fees were discussed in planning, but this option would require federal collection and disbursement. There currently is no mechanism in place to use this option, but the project team is following the trend and national discussion. Indiana has privatized and monetized its toll roads, so it has cash available to put toward the project if it chooses to use it. Congestion pricing was identified as an option in the EIS study but not seriously considered in planning. This mechanism is now on the list of financing options as a result of the significant increase in cost. Franchising was discussed for the extra cost of the East End section, but implementing this option seems unrealistic at present. However, the bistate group is considering all financing options.

New training in financial planning is probably not needed because Kentucky has been developing draw schedules for projects for some time so many project partners already know the process. GARVEE bonds have been used for ROW purchase in Kentucky, and the use of additional GARVEE bonds may be included in the bistate report.

Carbon credits are an unlikely option for the project. Louisville has poor air quality, but transportation is a minor contributor (coal-fired power plants are the major carbon emitter in the area). PPPs were not considered in the planning phase but are now being strongly considered given the significant increase in cost. Commodity hedging is not an option for the agencies and would have to be done by the contractor. Indiana had some pushback on their toll privatization effort caused by concern over non-U.S. ownership of state infrastructure, but that may not be a concern if the bistate group recommends some type of private financing option.

Inflation was the biggest financing risk, but it was not anticipated to be as significant as it was in 2003. Rapid increase in cost caused the construction phase to be put on hold. The project

team is attempting to model cash flow for the project, but financial modeling and capital expenditures will be somewhat determined by a bstate authority(BSA) report on how to fund the project.

The Kentucky Toll Authority was established several years ago, but currently Kentucky has no toll roads. Indiana has tolling authority. The BSA includes language identical to Kentucky's toll authority, so the legislative ability to implement tolls is already in place. However, Kentucky would need to develop organizational infrastructure for the toll authority. It is important to note that tolling authority is allowable in both states. A BSA with representation from all jurisdictions is examining financial strategies. The BSA will make funding and financing recommendation in December, which must be approved by upper bodies in both states. Any new bonding or taxes would require additional legislation.

To date, \$230 million in GARVEE bonds have been used for ROW purchase. ROW acquisition has been completed everywhere but in downtown Louisville. A second round of GARVEE bonds will be used by Kentucky for downtown ROW acquisition next year

The BSA is committed to the “two bridges, one philosophy” idea and the scope of the project as currently designed, so there is little chance that traditional financing can be used. As a result, all financing issues could potentially become more complicated. The original financing plan turned out to be inadequate, but design and ROW acquisition continued while a funding and financing plan is being developed. This added constraints to the project (cannot really redesign or reduce scope), so financing will be a major source of complexity. The relocation of the major transmission line downtown as well as downtown ROW acquisition will continue through 2011 while financing development proceeds, so there is “no turning back.” Therefore, it is difficult to

say that financing affected design, scope, cost, or delivery. Financing may have an effect on delivery method, but design, scope, and cost are driving financing, not the other way around.

Project Execution

The project is currently nearing the end of the design stage. Five of the six segments have final design documents. ROW acquisition continues on the Kentucky side, but project execution and procurement is on hold until a financing plan can be developed by the bistate commission.

Project Operation Phase

This project is at least 2 years away from this phase.

Summary

The massive project scope has led to financing problems that are preventing the project from moving forward. The 4(f) process has resulted in a commitment to extensive public involvement in design decisions.

Observations of the Researcher

Greatest Challenges

- Project size is extraordinary. This is the largest transportation project ever attempted in the United States, and the cost is \$4.1 billion.
- Availability of funding and no workable financing plan have halted the project. Even though rapid inflation in 2003 is mentioned as the cause of the unexpected cost increase, the formal risk management process was not started until 2007. It is the researcher's opinion that construction cost information was not incorporated in a timely manner, that risk analysis and management were not implemented early enough, and that the scope

impact of 4(f) commitments were underestimated. By the time a total final cost was tabulated, many irreversible design decisions (e.g., ROW acquisitions, Section 106 commitments, utility agreements, bridge locations) had been made. A key lesson learned is to have an idea of available funds early in the project, manage all planning and design activities to stay within those funds, and update project cost frequently.

-

Successful Accomplishments

- Working well with neighborhood groups,
- Good technical solutions for complex design issues (i.e., bridge towers, tunnels, industrial park interchanges),
- Extensive baseline documentation for project planning phase, and
- Use of visualization to enhance communication abilities.

Doyle Drive

Introduction

The Doyle Drive project, also known as Presidio Parkway, is a unique project that is one gateway to the Golden Gate Bridge. The Doyle Drive corridor, 1.5 miles in length, was originally built in 1936 to usher traffic through the Presidio military base to connect San Francisco and the Golden Gate Bridge. Doyle Drive is located in a high seismic hazard zone, and the original structure was not built to withstand projected earthquakes. A seismic retrofit was completed in 1995, which was intended to last for 10 years. The current project is comprised of eight separate contracts that will result in a new roadway, new structures that include bridges and

tunnels, and a depressed roadway section. The first and foremost goal of this project is to move the traveling public from the current questionable structure to one that is seismically safer. This report will detail the major issues encountered on the project, the lessons learned in the planning and design phases, and the tools used to manage this complex project.

Project Planning and Procurement

The Doyle Drive project has been in development for many years, with some documents dating back to the 1940s. The formal environmental process started in October 1999, and the EIS was signed in September 2008. During this time, the California DOT (CalTrans) explored different funding solutions, one being a new tax that was passed in 2007. The project team determined that splitting the project from one contract into multiple factors would facilitate faster accomplishment of the primary goal of the project, which is the safety of the traveling public. It was decided that the best course of action was to have eight different contracts split into two phases. Phase 1 includes four contracts with the purpose of (1) addressing environmental issues, (2) relocating all utilities from the project area, (3) replacing one of the viaducts, and (4) completing the depressed and tunnel sections of the project and detouring the public from the remaining project area to allow for Phase 2. Contracts 1 and 2 are emergency limited bid, and Contracts 3 and 4 are design-bid-build. The second phase of the project will be a PPP.

Cost

This project was originally intended to be one project; however, the estimated cost of the project was more than \$1 billion. A local agency came forward and offered to help with funding if the project could be completed sooner. This offer helped to prompt the division of the contract into

eight contracts. Contract 3 was estimated to cost \$120 million; however, the low bid was \$60 million.

Effective tools for managing cost complexity are

- Monte Carlo estimates with risk;
- Cost Reduction Incentive Proposal (initiated by the contractor and cost savings shared between the contractor and CalTrans);
- Cost effectiveness study;
- Partnering;
- Dispute resolution process; and
- Risk management plan.

Schedule

Getting traffic off the current structure is the most important aspect of this project.

Effective tools for managing schedule complexity are

- Multiple contract types;
- Partnering;
- Dispute resolution process;
- Cost-effectiveness study that looks at cost and time; and
- Risk management plan.

Technical

A number of historic buildings and other considerations are in the area. The Presidio was listed as a National Historic Landmark District in 1962, and in 1966, was listed on the National Register of Historic Places. The project also passes closely by a national military cemetery.

Effective tools for managing technical complexity are

- Define project requirements for the construction phase, including vibration limits, and so forth.
- Use video survey of buildings pre- and postconstruction.
- Allow construction staff to work with the project management and designers early in project development to perform enhanced constructability reviews.
- Build temporary shoring walls to protect cemetery graves.
- Use strain gauges for measuring wall deflection.
- Commit to partnering.
- Define dispute resolution process.
- Use restaging to simplify job.
- Tailor structure to fit project needs.
- Use 3-D and 4-D modeling of the project
 - Worked with Google Earth to develop a model of what the future Doyle Drive would look like (this was also done on the Bay Bridge).

Context

As mentioned in the technical section, this site includes a number of identified contextual factors that include historic buildings and grave sites. This site is also adjacent to the Walt Disney Family Museum.

Effective tools for managing context are

- Extensive public outreach including meetings and walking tours.
- Partnering.
- Dispute resolution process.
- Draft specifications issued with stakeholders for input.
- “Clear the way” meetings for the internal structure to find out and work through the project issues.
-

Financing

The funding for this project is coming from 21 sources. Each source has its own process, constraints, monitoring, and reporting.

An effective tool for managing financing is to stay on top of problems.

Project Execution

Cost

The economy has affected this project, and bids are coming in substantially lower than estimated. This has caused CalTrans to request less funds to support this project.

Effective tools for managing cost complexity are

- Detailed monthly update reports that include information on all of the contracts. The update report details
 - Project Management Report

- Progress Summary
- Schedule
- Budget/Expenditures
- PPP Update
- Risk Management
- Construction Progress Report
- Small Business Report
- Public Outreach Report
- Value engineering
- Cost Reduction Incentive Proposals

Schedule

The number one goal is the safety of the traveling public, which means getting the public off the viaduct that is currently used to access the Golden Gate Bridge. The project was divided into multiple contracts to facilitate the desired goal. This included splitting the utility work into a separate contract that was let before the start of construction. This contract requires clearing of utilities from the corridor.

Effective tools for managing schedule complexity are

- The philosophy that every day counts as a working day, including weekends, holidays, and inclement weather days.
- Incentives and disincentives for meeting milestone dates. An incentive can be \$50,000 per day up to a specified cap.

- Detailed monthly update reports that include information on all of the contracts. The update report details
 - Project Management Report
 - Progress Summary
 - Schedule
 - Budget/Expenditures
 - PPP Update
 - Risk Management
 - Construction Progress Report
 - Small Business Report
 - Public Outreach Report
- Separate contracts and multiple contract types
- Overlap contracts
- Having a consultant schedule all activities for all contracts
- Tackling and resolving one issue at a time and resolving issues as they come up, not putting them off until later
- Working with local stakeholders to get approval of two 10-hour shifts

Technical

The number of historical buildings and national park sites in the area creates the need for continued monitoring and assessment of construction impacts. In addition to the above ground limitations, geological investigations show layers of beach dune, colma sand, old bay mud,

fractured rock, and groundwater before piles can reach bedrock. The piles are needed for the high viaduct on the project and require 12-foot-diameter cast-in-drilled hole piles and rock sockets.

Effective tools for managing technical complexity are

- Video survey of buildings pre- and postconstruction
- Vibration and crack monitoring
- Full depth steel casings for the piles
- Detailed monthly update reports that include information on all of the contracts. The update report details
 - Project Management Report
 - Progress Summary
 - Schedule
 - Budget/Expenditures
 - PPP Update
 - Risk Management
 - Construction Progress Report
 - Small Business Report
 - Public Outreach Report

Context

The local area is very involved in this project, and national leaders are very aware of this project, including some who are in the area.

Effective tools for managing context are

- Noise monitoring;
- Archeological monitoring
- Tree protection and preservation plan
- Project Arborist
- Biological monitoring and training for all contractors
- Extensive public outreach including meetings and walking tours
- Detailed monthly update reports that include information on all of the contracts. The update report details
 - Project Management Report
 - Progress Summary
 - Schedule
 - Budget/Expenditures
 - PPP Update
 - Risk Management,
 - Construction Progress Report
 - Small Business Report
 - Public Outreach Report
- Working with local stakeholders to get approval of two 10-hour shifts
- Demonstrating the need for night work

Financing

The funding for this project is coming from 21 sources. Each funding source has its own process, monitoring, and reporting. One source of complexity has been that the federal money has a buy-American requirement. This caused a specific issue for some steel fins for the viaduct. The fins need to be similar to current pieces and must match the surrounding aesthetics. Fins were found that were made in another country, and a waiver was requested but not accepted. A firm was then found in the United States, but the price of the fins increased by several million dollars.

Effective tools for managing financing are as follows:

- Detailed monthly update reports that include information on all of the contracts. The update details
 - Project Management Report
 - Progress Summary
 - Schedule
 - Budget/Expenditures
 - PPP Update
 - Risk Management,
 - Construction Progress Report
 - Small Business Report
 - Public Outreach Report
- Staying on top of problems
- Using cash flow software

Project Operation Phase

This project is not yet at this phase.

Observations of the Researcher

This is a project that is very much visible in the eyes of the country, or could be, if things do not go right. Being in the vicinity of a national park, national historic places, and the Golden Gate Bridge means that everything needs to go well on this project. In addition, given the status of the structures on the project and the national attention on catastrophic failures, it is critical that this project be completed as soon as possible. The schedule is being addressed in a number of ways with various tools, that is, the use of multiple contracts and different delivery methods. Moreover, some of the tools being used are intangible, such as open, transparent communication with stakeholders. Even less obvious is the effort made by the project staff to stay current on the project and everything that is going on and to address issues proactively and quickly.

Detroit River International Crossing

Introduction

The Detroit River International Crossing (DRIC) project is a U.S.–Canadian connection consisting of five primary elements: a new Detroit River Crossing (bridge); inspection areas on each side of the river for the respective border services agencies of the United States and Canada (plazas); and connecting roadways to I-75 in Detroit and Highway 401 in Windsor.

The purpose of the project for the foreseeable future (30 years) is to

- Provide safe, efficient, and secure movement of people and goods across the U.S.–Canadian border in the Detroit River area to support the economics of the state of Michigan; Ontario, Canada; and the United States; and
- Support the mobility needs of national and civil defense to protect the homeland.

The Detroit River separates the United States and Canada, with current crossings at the Ambassador Bridge (four lanes), the Detroit–Windsor Tunnel (two lanes), the Detroit–Canada rail tunnel, and the Detroit–Windsor truck ferry, which serves oversize and overweight vehicles and vehicles carrying hazardous cargo (see figure B.29). These multimodal transportation links provide the connections for freight and passenger movements between the two countries. Miles-long lines formed at each of these crossings, and new security measures put in place after the terrorist attacks of September, 11, 2001, further complicated the congestion problem.

In 2000, FHWA, the Michigan DOT (MDOT), Transport Canada, and the Ministry of Transportation for Ontario agreed to study the border crossing needs for the southeast Michigan–southwest Ontario border crossing area to address both the existing issues and any additional issues that could be anticipated in the next 30 years.



Figure B.29. Project area map.

General Project Overview

Bridge

In general terms, the new Detroit River Bridge will connect the Delray area of the city of Detroit and the Brighton Beach area of Windsor, Canada. The new bridge will be either a cable-stayed bridge or a suspension bridge depending on what decision is made during the design phase of the project. The bridge will be publicly owned and controlled.

The bridge will have a cross-section of six 12-foot-wide travel lanes (three in each direction), 10-foot-wide outside shoulders, a 3-foot-wide flush median, and a 5-foot-wide sidewalk on either side of the bridge.

Plaza

The bridge will connect on the U.S. side to a plaza that covers approximately 170 acres. The plaza will consist of a U.S. federal inspection station (FIS) and operating authority facilities. This plaza will be jointly managed by the General Services Administration and an operating authority (options include MDOT, concessionaire, or the bridge authority, all dependent on the governance

structure adopted for the project). The FIS area will include federal agencies such as the U.S. Customs and Border Protection and the U.S. Department of Agriculture Animal and Plant Health inspection.

Link to I-75

The plaza will directly connect to the freeway via a Y-style interchange centered near Military Street. The ramps will be elevated over existing NS/CSX rail lines and over a local street.

Project Planning and Procurement Phase

Action Taken	Date
Final Environment Impact Statement (FEIS) signed	November 21, 2009
Record of Decision (ROD) signed	January 14, 2009
Canadian Environment Study approved	Late 2009
Preliminary design activities initiated.	2009
Met the May 1, 2010, reporting requirement to the Michigan legislature; awaiting legislation to move forward with the project	2010

Delivery Method

The preferred delivery mechanism for the bridge is a PPP in the form of a long-term concession agreement that will seek to maximize private-sector participation and financing to avoid the use

of taxpayer dollars. The intent is for the bridge to be financially self-sustaining from a reasonable toll charged to its users. It is envisioned that the owners will form a joint venture to oversee the concession contract with the private sector. The U.S. and Canadian governments are committed to private-sector involvement for any combination of the design, financing, construction, operations and/or maintenance of the bridge crossing. The partnership will provide oversight of any private-sector participation to ensure a safe and secure international border crossing.

Currently, Michigan needs to have legislation to authorize a PPP for this project. The bridge across the river and all, or part of, the U.S. plaza will be developed in cooperation with various private-sector participants in the finance, design, construction and/or operation and maintenance of such facilities. It is envisioned that the bridge concession, if approved, will be done in conjunction with Transport Canada.

Other options to maintain momentum on the project if the PPP legislation does not pass is to have legislation authorizing the creation of a new bridge authority to operate and maintain the DRIC bridge.

Should a PPP not be feasible, authorization to sell revenue bonds is another option that would be secured by tolls from the bridge and lease payments from some of the plaza users.

All options requiring collection of tolls on the bridge require legislation. The challenge to any of the legislation needs is the competing Ambassador toll bridge, which is privately owned and operated. Since the DRIC is in competition with the Ambassador bridge, there is political sensitivity to authorizing legislation to support the completion of the project.

Cost

The project's estimated baseline is between \$1.809 billion for the cable-stayed bridge option and \$1.814 billion for the suspension bridge option on the basis of year of expenditure. These costs are at an 80% confidence level that is based on FHWA's cost estimate review conducted for the project in November 2008.

Schedule

The current schedule for the project plans on opening to traffic by December 31, 2015. This is ambitious. Delay is a significant risk to the economics in the region. The cost of not completing the project on time is on average \$58 million per year.

Technical

The project team was framed around managing risks and focusing on those items that were or are on the critical path. Key elements that supported the project goals and objectives and successfully management of the project are the following:

- Procuring a consultant coordinator, who worked directly with the assigned project manager and was responsible for coordination and monitoring of the other selected consultants and all other aspects of the total project.
- Using an Aesthetic Design Guide (ADG) to implement the outcomes of the context-sensitive solutions (CSS) process by specifically illustrating the design intent, design features, and enough detail to demonstrate to the stakeholders that the commitments made during the NEPA process are incorporated into the final design and into construction. The first phase of the ADG is to define visual issues and impacts, goals and

priorities, and conceptual aesthetic features and elements; the second phase will generate design requirements and alternative design concepts and refine a preferred set of design elements for integration into the plans, specifications, and estimates.

- Separating design consultants by distinct project limits and scopes of services (freeway interchange design consultant, interchange bridge design consultant, ADG consultant, oversight consultant).

All contracts and procurements will be executed using MDOT's standard procedures.

The PPP concessionaire selection will be done cooperatively between MDOT and Transport Canada. The concession is currently seen as spanning 30 to 45 years. The selection will include a value-based process to include cost, creative construction methods, schedule, and a good-neighbor policy to ensure that commitments to environmental mitigation and enhancements are met and, if possible, improved upon.

Context

Organizational structure, project partners, and governance

To have basically four organizations cosponsoring this project offers a lot of challenges and opportunities. The collaboration and framework established at the beginning of the project scoping through the NEPA process has been successful. As the project proceeds through design and construction, the main framework will be in place; however, individuals and resources will be assigned to adapt to the specific stage of development.

Partnership Steering Committee. The committee consists of the governments of Ontario, Canada; the State of Michigan; and the U.S. government. The specific agencies involved are the Ontario Ministry of Transportation, Transport Canada, MDOT, and FHWA. The partnership committee is committed to maintaining public oversight of the crossing and has established that it will be governed by one of several models:

- Government owned and operated (similar to the U.S. half of the Blue Water Bridge);
- Public–private partnership—concession with government ownership;
- Binational authority (similar to the International Bridge at Sault Ste. Marie, Michigan) with government ownership; or
- Private sector owned and operated with government oversight.

Working Group. The group is made up of the project managers and technical staff assigned to the project from the four primary governmental agencies.

Other. More than seven other federal agencies are involved with the project, and more than eight state and local agencies are intimately involved with the project.

Project Context—CSS

All elements associated with environmental analysis were evaluated as required, and specific items that were critical to this project include the following:

- Protect community and neighborhood characteristics, including environmental justice and Title VI populations;
- Maintain consistency with local planning;
- Protect cultural resources (including parkland);

- Protect the natural environment;
- Improve regional mobility;
- Maintain air quality; and
- Constructability.

Public Engagement and Outreach

The project team consistently applied CSS principles to its project approach. Specifically, MDOT has conducted various meetings to offer opportunities for public comment and participation during the DRIC study process. Almost 100 public meetings, hearings, and workshops have been held to facilitate public involvement. The methods used and information presented were guided by a public involvement plan established at the outset of the project and refined as it unfolded. Access to the study by a toll free project hotline (1-800-900-2649), by written comments through the project website (www.partnershipborderstudy.com), or by mail was available and encouraged through the study process. A DRIC Study Information Office is located at the Delray Community Center in Detroit to provide information and to answer questions about the project. Approximately 10,000 residences and businesses were sent mailings about each formal public meeting. In addition to the mailings, more than 1,000 fliers were handed out door-to-door in Delray and along the I-75 service drive north of the freeway for public meetings and workshops.

Financing

Currently, the project development correlates directly to the mechanism chosen to finance the project, which is to pursue a PPP for the bridge and for either all or a portion of the plaza. Alternative funding methods considered include having either MDOT or a new bridge authority

sell revenue bonds, secured by future tolls from the bridge, to finance the construction of the bridge and all or portions of the plaza

Project Execution

This project is still in the preliminary design phase.

Project Operation Phase

This project is still in the preliminary design phase.

Reference

Detroit River International Crossing – Project Management Plan Final Environmental Impact statement <http://partnershipborderstudy.com/news.asp>.

Richmond, Virginia, I-95 James River Bridge

Introduction

The I-95 James River Bridge project in Richmond, Virginia, consists of the restoration of the 0.75-mile-long James River Bridge on I-95 through the central business district of Richmond, Virginia. The bridge is 4,185 feet long, six lanes wide, and a maximum of 96 feet high. It was built in 1958 to carry one-third of the 110,000 vehicles per day it carried when it was rebuilt in 2002. The contractor proposed to use preconstructed composite units (PCUs), which consisted of an 8.7-inch concrete deck over steel girders fabricated nearby. Crews cut the old bridge spans into segments, removed them, and prepared the resulting gaps for the new composite unit. Last, the crews set the new prefabricated unit in place overnight. The project also included

improvements to widen Route 1, the Jefferson Davis Highway, enhance signalization, and install a high mast lighting system. Figure B.30 shows the alignment for this project.



Figure B.30. Richmond, Virginia, I-95 James River Bridge restoration project aerial view.

Project Planning and Procurement Phase

The planning and procurement phase started when the Virginia DOT (VDOT) filed a Notice of Intent (and FHWA announced its Environmental Impact Statement) to restore 13 structurally deficient bridges on I-95 from the James River on the south to the I-95/US-/301 interchange on the north end of the corridor that carries traffic through the Richmond, Virginia, central business district (3). VDOT selected URS-Greiner as the engineering design firm for the project in June 1998. Construction was under way in March 1999 with the start of the off-bridge improvements

to the substructure, the precast yard, and the Route 1 improvements. After these were complete, the reconstruction of the northbound side of the bridge began in June 2000.

Cost

The original cost for the project was \$43 million in 1999 dollars. This figure includes a contingency for those unforeseen factors that would not be known until actual demolition of the existing bridge.

Schedule

The original schedule was split into two components: work that could be accomplished without disrupting traffic and work that would require traffic control.

This division of activity created an element of complexity in that dividing the two scopes of work before design was complete caused a number of assumptions that later had to be validated before advertising the project.

Technical

The planning phase for the engineering and design of the project was focused on evaluating alternatives to demolish and replace the portions of the bridge in the most-efficient manner. A traffic study was initiated to evaluate the consequences of each scenario shown in Table B.2. Various accelerated bridge construction techniques were also evaluated.

Table B.2. James River Bridge Construction Options Analysis (3)

Option	Advantages	Disadvantages	Estimated

			Duration
A. Conventional construction: <ul style="list-style-type: none">▪ 1 lane open in each direction▪ Lane closures every day	<ul style="list-style-type: none">▪ Safest▪ Familiar▪ 3 lanes merge to 2, not 1▪ Access for emergency vehicles	<ul style="list-style-type: none">▪ Affects everyone▪ Commuter peak periods▪ Tourists/business impact▪ Longest time	24 to 36 months
B. Night-only construction: <ul style="list-style-type: none">▪ Construction 7 p.m. to 6 a.m.▪ 3 lanes open in day▪ 1 lane each way at night▪ Diverts traffic to other side of bridge	<ul style="list-style-type: none">▪ Least inconvenient▪ Shortest duration▪ 3 lanes open in day when they are needed most	<ul style="list-style-type: none">▪ Huge jam if all lanes not open at 6 a.m.▪ Merging safety issue▪ Must assure emergency vehicle access	12 months
C. Weekend Construction: <ul style="list-style-type: none">▪ Construction Friday p.m. through Monday a.m.▪ 1 lane each way on weekends	<ul style="list-style-type: none">▪ Best for business▪ No impact to commuters or night deliveries	<ul style="list-style-type: none">▪ Negative public sentiment; kill tourist industry▪ Long duration▪ Merging safety issue▪ Residents affected on weekends	21 months

Context

The context issues that VDOT primarily focused on in this phase were public opinion and procurement constraints.

Public Relations

The context of public relations, including that of various state and city organizations, was very important to VDOT in the planning stage. VDOT mounted a full-scale public relations and information campaign almost as soon as the project concept was approved. VDOT made a concentrated effort to ensure that the residents and business leaders of Richmond were involved in the process to bring the most-suitable solution to restoring structural integrity to the bridges on I-95 that run through the heart of the city. The planning process from inception to completion took 3 years. The plan's primary goal was to minimize impact on the traveling public and the community during construction. The centerpiece of the public information (PI) plan was to modify travelers' behavior by influencing them to "self-detour" and avoid the area once construction had commenced. Figure B.31 shows the desired detour route for I-95 through-traffic. It shows the interchanges of I-95 and I-295 north and south of Richmond. The southern interchange is actually several miles south of Petersburg. This route is of primary interest to Interstate trucking firms that ply the East Coast. The loop around Richmond adds approximately 30 miles to the trip. Part of the PI effort was to contact these firms 2 years before construction started and encourage them to begin planning to reroute their trucks during the construction period. The second part of the self-detour plan was for commuter traffic. This, too, was commenced at the outset of the planning phase (2). For example, the summer 2001 edition of the

I-95 Bridge Restoration Newsletter (7) contains an article with a warning to commuters: “If you use this stretch on I-95 to get home in the evening, you should look for an alternate route once construction begins in 2003.” Variable message boards were deployed throughout the corridor to announce the upcoming lane closures a year in advance.

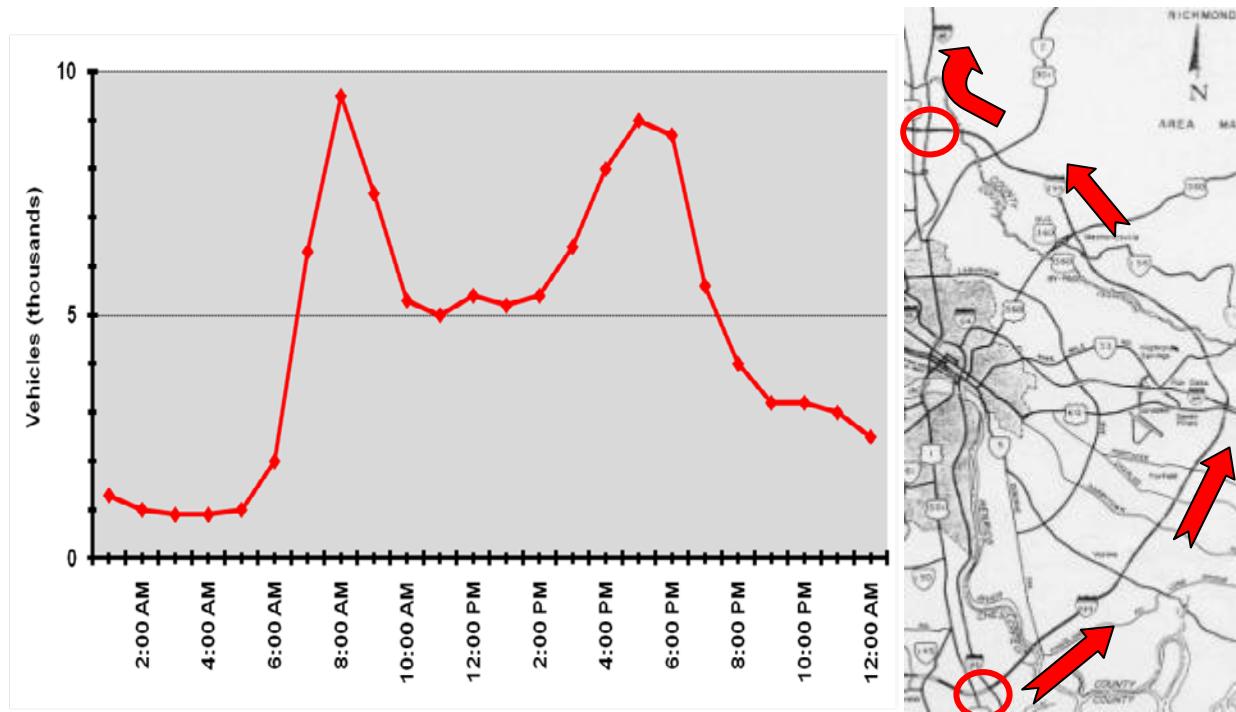


Figure B.31. Average hourly traffic and desired self-detour to avoid Richmond (4).

Three possible construction options were analyzed in conjunction with the engineering design consultant to determine which one furnished the best opportunity to minimize impact to traffic and downtown business interests. Table B.2 furnishes the details of each as well as the pros and cons developed by VDOT and its consultant. VDOT then sought the advice of a Community Advisory Group (CAG) composed of members of the Downtown Chamber of Commerce and other concerned citizens. This group evaluated each option and recommended that Option B be used for the following reasons:

- Best meets traffic demands,
- Is the most flexible option,
- Causes the least inconvenience,
- Has the shortest construction timetable, and
- Can ensure a lane for emergency vehicle use (3).

VDOT and the CAG then jointly developed the goals and objectives for the PI plan that would be implemented in support of Option B. Those goals are as follows:

- Raise awareness of construction before on-site work begins,
- Minimize traffic delays,
- Promote alternate routes, and
- Maintain VDOT's positive image (3).

Procurement Constraints

During the planning phase, VDOT decided to use A+B contracting. It was believed that this contract form would encourage the bidders to minimize the amount of time traffic would be disrupted. It was also believed it would encourage innovative construction means and methods (8). Finally, the use of design-bid-build (DBB) did not require VDOT to submit a request for SEP-14 authorization, which allowed the planning and procurement process to proceed without the delay of awaiting the results of that application.

Financing

As mentioned earlier, this is a public project financed by federal aid dollars and state matching funds. Financing did not play a significant part in adding complexity to the project. The primary issue was the need to implement the incentive and disincentive (I/D) provisions in a meaningful way that would encourage innovative construction means and methods to minimize impact on both the community and traffic.

Project Execution

The project was completed in 2002. One hundred and two sections were replaced thanks to the contractor's proposal for redesigning the bridge demolition and for reconstruction to be conducted in two sections, rather than using the engineer's design for three sections.

Cost

The cost during the execution period remained within early estimates except for changes to repair previously unknown structural deterioration to pile caps and the requirement to abate lead-based paint on the structural steel elements of the old bridge that had not been visible until they were exposed during demolition. These changes cost \$6 million and included a \$1.3 million early finish bonus.

Schedule

The schedule for the construction during the execution period of the project was driven by the context of the project. The contract contained a special provision that divided the work into two stages. Stage 1 entailed all work that could be completed before implementing traffic control (6).

The north and southbound bridge replacements were Stage 2. The project proceeded in two major periods:

1. Stage 1 work packages plus the Stage 2 northbound bridge replacement; physically began June 16, 2000, and was completed on June 19, 2001.
2. Stage 2 southbound bridge replacement; physically began August 9, 2001, and was completed on November 27, 2001 (3).

The project was completed early in spite of several unforeseen conditions.

Technical

The element of technical complexity during project execution was the redesign of the bridge to accrue the benefits from the contractor's proposed construction sequence of work. Figure B.32 is a drawing that was provided to illustrate the concept. The proposed change was elegant in that it reduced the number of sections to be removed and replaced by one-third and permitted the reduction in the number of nights that free flow of traffic would be affected by nearly 25% (from 179 scheduled to 137).

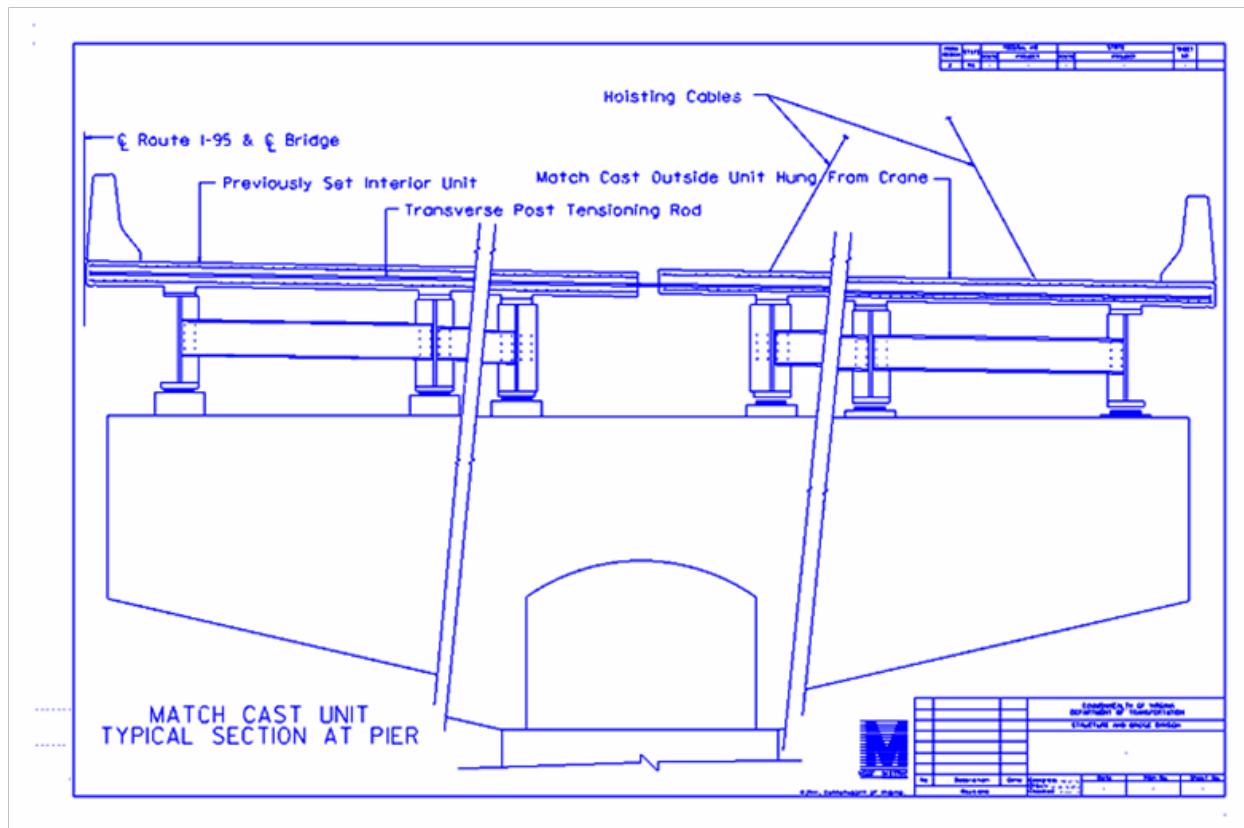


Figure B.32. Contractor-proposed change to bridge to use two sections (3).

Obtaining contractor input in the design process before award would have been valuable. However, the DBB project delivery method precludes it. Nevertheless, VDOT was open to contractor input after award. The result was a substantial loss of preaward design effort that was offset by a significant benefit accrued in construction. Figure B.33 shows the demolition–construction sequence that was finally implemented. It can be seen that the system of prefabricated bridge elements is very efficient and able to increase “construction zone safety, minimize the traffic impacts of bridge construction projects, make construction less disruptive for the environment, and improve constructability. Safety is improved and traffic impacts are lessened because some of the construction is moved from the roadway to a remote site,

minimizing the need for lane closures, detours, and use of narrow lanes. Moving the construction from the roadway can also lessen impacts on the surrounding environment” (*I*).



Figure B.33. Demolition–construction sequence (3).

Context

Solutions to the context issues implemented during planning and procurement were continued in greater intensity during execution. The self-detour planning paid dividends by reducing the

average hourly weekday traffic at 7 p.m. from 4,800 to 3,000 vehicles per hour (2). The value of the PI plan was accrued, as described by Andrew Zickler, VDOT's structural design program manager:

“Make sure that you have a public communications plan in place, this was probably the most public information on any project in Richmond and the VAST majority of public comment was positive” (8).

The CAG had weekly meetings on the progress of the project, and the relationships made during the planning phase were kept alive and positive, whether with the public, railroads, or the leadership of the Richmond Downtown Chamber of Commerce (DCoC). VDOT and the contractor were open to making minor adjustments in the construction schedule to accommodate downtown businesses with specific needs, such as changing the full-closure timing to permit a large delivery that had to be made during active construction. As a result of the PI program’s success, VDOT was presented the AASHTO Excel Award for Excellence in Public Relations.

The actual impact on the traveling public was minimized by using a movable barricade system to expeditiously shift traffic in the evening. Figure B.34 illustrates how this was done. In addition, a wrecker service was provided to quickly remove disabled vehicles from the construction work zone and maintain the flow of traffic during construction hours.



Figure B.34. “Zipper” movable barrier in action (3).

Financing

The financing was not a major issue. However, the unforeseen site conditions described below required VDOT to seek additional funding to pay for these changes.

Project Operation Phase

This project has been in the operation phase for 9 years. To date, the major issues are as follows:

- “The polymer concrete is not the perfect material, it is highly sensitive to surface prep and we have had some joint issues along the way, both immediate and several years later.
- Watch out for new products, we have had significant issues with the Cathodic Protection provided as well as some issues with polymer concrete.
- The post tensioning worked for what we needed it to (close the joints), but it may not be performing to the extent of reducing live load (we hoped it would, but we did not reduce beam designs to count on it).

- The milling which was anticipated was not performed and the ride is a little rough you can feel the P/S continuity joints as well as the normal joints.” (8)

Overall, VDOT is satisfied with the product and since then has used the same process on the other eight bridges on the I-95 corridor. These bridges are shown in Figure B.35. It can be seen from the number of bridges and their location on I-95 that the rapid renewal tools that VDOT developed on the James River Bridge project were effective, efficient, and added value to the design and construction of a very complex project.



Figure B.35. VDOT I-95 bridge restoration program using PCU construction sequence.

Summary

After meeting with Andrew Zickler, the PE manager of VDOT's structural design program, it was concluded that this complex project has been so successful because of five major factors:

1. VDOT invested a significant amount of time and management energy in the planning phase. The DOT held multiple public meetings, involved community interest groups in the planning phase, and implemented its PI plan as early as possible.
2. VDOT used tools such as the “self-detour” PI information campaign and empanelling a Community Advisory Board to deal with project context issues before construction started.
3. VDOT leveraged the A+B and I/D contracting variations on DBB project delivery to create a contracting environment that encouraged bidders to seek solutions that ultimately led to achieving the project’s primary goal of minimizing impact on the community and the traveling public.
4. After awarding the construction contract, VDOT was willing to implement a contractor-proposed initiative that involved a significant redesign of the project but furnished a more constructible solution.
5. VDOT built a project management team and fostered an attitude of seeking pragmatic solutions to technical and context problems that supported mutually developed project goals. This institutional flexibility and open-minded acceptance of good ideas created an environment for project success.

These reasons have combined to work throughout all of the context, financing, technical, cost, and schedule issues of the project.

Observations of the Researcher

This project would have benefited from the use of construction-manager-at-risk project delivery. The fact that VDOT permitted the contractor to essentially change the design demonstrated how early contractor input would have facilitated the project and would also have furnished an additional tool in the planning and design phases to control complexity.

Greatest Challenges

- Addressing political sensitivity issues due to the project's location in the heart of the central business district and adjacent to the Virginia State Assembly building,
- Maintaining traffic flow in a manner that did not adversely affect businesses serviced by the I-95 corridor through Richmond,
- Implementing a contracting scheme that encouraged innovative construction means and methods, and
- Trusting the construction contractor to improve the design after award to enhance constructability.

Successful Accomplishments

- Leveraged contractor input in the redesign process to the benefit of the project,
- Maintained nonadversarial relationships with the public,
- Kept everyone's best interests in mind,

- Created an environment of rich and timely public information,
- Provided for a project planning phase that was extremely in depth,
- Committed necessary resources ahead of time,
- Solved a lot of potential problems early,
- Implemented a PI campaign at the earliest possible time and kept the public's "vision" on events that were up to 2 years in the future,
- Created a special provision with graduated consequences that matched a penalty with amount of time traffic was disrupted, and
- Built a team that was able to capture lessons learned from this project and could leverage those for use on a series of future projects on the same corridor.

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Washington, D.C., and Baltimore, Maryland, InterCounty Connector

The InterCounty Connector (ICC) has been planned and studied for more than 50 years, and its design was developed with extensive involvement by Montgomery and Prince George's counties in Maryland. The new east–west highway will cover approximately 18.8 miles and will include the construction of numerous new highway interchanges and bridges (see Figure B.36). The ICC will be a state-of-the-art, toll-operated, multimodal roadway with limited points of access.

The ICC project will provide a myriad of benefits to the Washington, D.C., and Baltimore, Maryland, metropolitan areas. It is intended to increase community mobility and safety; facilitate the movement between economic centers of people and goods; provide cost-effective transportation infrastructure to serve existing and future development that reflects local land use objectives; help restore the natural, human, and cultural environments changed by past development impacts; and enhance homeland security.



Figure B.36. ICC during construction.

Currently, the project consists of five separate construction contracts and 47 separate environmental stewardship and mitigation contracts. These are shown in Figure B.37.

Project Planning and Procurement Stage

The initial environmental studies began in 2004, and the first construction segment of the project started in November 2007. Only three of the five construction contracts have been fully let out, all using design-build procurement. Each segment is scheduled to open incrementally with the bid out projects expected to finish in late 2011. The final two contracts (D and E) are yet to be determined for letting periods and anticipated completion. Along with the 18 miles of mainline construction, nine interchanges, one intersection, two bridges, 4 miles of existing highway reconstruction, and 4.9 miles of resurfacing are slated to be completed during this project.

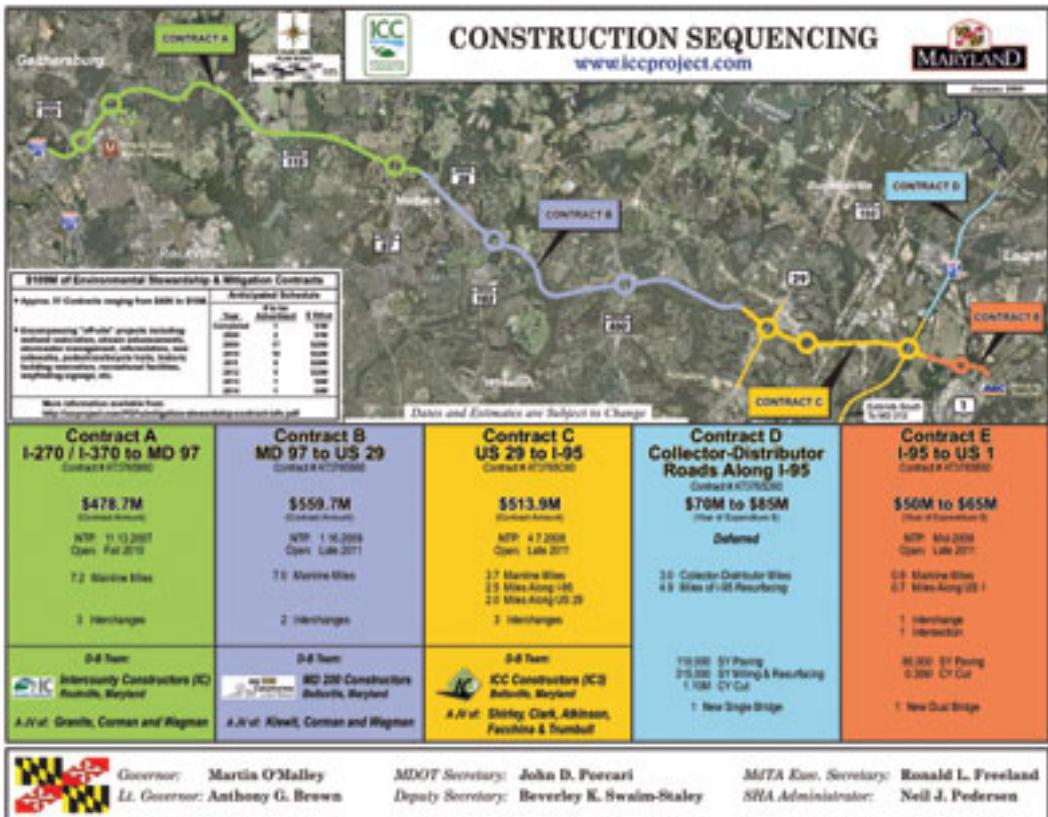


Figure B.37. Color-coded construction contracts.

A summary for each of the active contracts (A, B, and C) is shown in Figure B.37; details are listed below.

Contract A

The first contract, Contract A, was advertised in summer 2006 (see Figure B.38).

I-270/I-370 to MD-97

- Design and construction of the first segment of the ICC, extending from I-270/I-370 to approximately 600 feet east of MD-97;
 - Approximately 7.2 miles of six-lane highway; and

- Three interchanges: I-370/MD-355, I-370/Shady Grove and metro access roads, and ICC/MD-97.



Figure B.38. Contract A.

Contract B

The second contract was Contract B (see Figure B.39).

MD-97 to US-29

- Design and construction of the ICC extending from approximately 600 feet east of MD-97 to west of US-29;
- Approximately 6.9 miles of six-lane highway; and
- Two interchanges: ICC/MD-182 and ICC/MD-650.



Figure B.39. Contract B.

Contract C

The third contract was Contract C (see Figure B.40).

West of US-29 to East of I-95

- Three interchanges: ICC/US-29, ICC/Briggs Chaney Road, and ICC/I-95;
- Approximately 3.8 miles of new six-lane ICC highway, 1.3 miles of US-29 road improvements, and 1.9 miles of I-95 auxiliary lane and C-D roadway improvements; and
- Construction involving interchange structures over the existing and heavily traveled US-29 and I-95, and depressing the ICC under the existing Old Columbia Pike, Briggs Chaney Road, and Old Gunpowder Road, while maintaining existing traffic on them.



Figure B.40. Contract C.

Cost

The total anticipated cost is approximately \$2.566 billion, with \$109 million accounting for the environmental contracts.

The ICC set aside contingency for change orders (COs) which will be used for the \$100 million gap in financing related to a cost impact on Contract B (bids came in significantly over budget). The ICC also set aside an environmental incentive pool for each contract to incentivize contractors to reduce environmental impacts.

To take material contingency out of the bids, the ICC used price adjustments in contracts for asphalt, concrete, steel, and fuel, with a cap on cumulative price adjustments at \$10 million, and a cost overrun will be shared. All four materials were capped at \$10 million together.

On the basis of ratings, the ICC used cost incentives and disincentives (the contractors have to pass all quarterly ratings for incentives). The ICC used tough love to develop the rating system. This approach was used on a DB lump sum job so that corners were not cut. Each contract had separate pools of money for incentives.

Schedule

In terms of scheduling, the ICC started procurement before planning was completed. Partial NTPs started design with pending environmental litigation. Changing ROW requirements, longer bid process, less time to construct, and scheduling three projects at one time added to complexity.

Financing

The project is using multiple funding sources and will be part of Maryland's tolling network upon completion. GARVEE bonds, the MDOT pay-as-you-go program, special federal funds, Maryland Transportation Authority (MdTA) bonds, Maryland general fund transfers, and a TIFIA loan are all sources of funding being used for this project. A breakdown of the financing is as follows:

- \$750 million in GARVEE bonds,
- \$715.6 million in authority toll revenue bonds and cash (MdTA),
- \$516 million in TIFIA loans,
- \$264.9 million in state general funds,
- \$180 million in state transportation trust funds,
- \$19.3 million in special federal funds, and
- \$16.9 million in additional funds from GARVEE sale.

The above figures add up to a commitment for the project of \$2.4627 billion. Anticipated funding for Contract D (outside the 6-year program) is \$103.2 million, and options are still being worked out. These components bring the anticipated total to \$2.566 billion.

Technical

In regard to the internal organizational structure, the ICC used a completely new structure with unfamiliar roles and levels of authority. A dedicated team of five staff from the state highway authority (SHA) manage the program with consultant staff (REs) reporting to the SHA on projects. The SHA project manager has immediate access to the administrator and the information flow. The delegation of authority allows REs (from the consultant staff) to make decisions related to technical issues. The SHA had to become comfortable about allowing consultants to make decisions. Cost and time decisions were not allowed by the REs, but they could do the homework for those decisions. This was viewed as a very effective separate organization to run the program,

Public outreach and input was extensive and included interagency workgroup meetings monthly (on website), and quarterly P+1 (principal + i.e., project manager meetings).

The scope changed from initial planning stages. NEPA requirements changed the scope over time. The ICC environmental requirements added complexity to the work. The concept involved building through parks, and the motto was to “tread lightly on land.” The ICC scope also included the first electronic-only tolling in Maryland.

The ICC used performance specifications that provided visualizations to the public as well as significant latitude in materials and technology. The specifications allowed GCs to use

various databases, which added to complexity by incorporating different interfaces and different business model systems.

Context

In regard to public expectations, the public expected to see what they were going to get, and the project was not received well at the 30% design completion stage. There was significant external influence and issues with land jurisdictions and various sets of constituents.

The ROW costs were very high with more than 400 properties involved. Nothing was simple about the ROW process.

The ICC built visual models to show design ideas to the public and formed an interagency working group. Extensive coordination was required for environmental streamlining. Informal briefings were made to politicians, and monthly briefings were given to engage local jurisdictions in decisions. A tracking log was used for coordination for ROW.

Project Construction Phase

Cost and Schedule Status for Individual Contracts

Contract A

7.2 mainline miles, bridges including over rail lines, interchange, utility relocations, noise wall installation, ITS, and electronic toll collection

- \$478.7 million;
- 0.1% of base in (COs) thus far; and

- Limited NTP June 2007, full NTP November 2007, projected completion September 2010.

Contract B

7.0 mainline miles, noise walls, utility, bridge designs, detours, bridges

- \$559.7 million;
- 0.0% of base in COs thus far (actually a deduction); and
- Limited NTP October 2008, full NTP January 2009, projected completion December 2011.

Contract C

Bridges, wetlands impact, 3.7 mainline miles, 4.5 miles of reconstruction, interchanges, utility relocations

- \$514 million;
- 0.2% of base in COs thus far; and
- Limited NTP January 2008, full NTP April 2008, projected completion December 2011.

Contract D

- Delayed until fiscal year 2016.
- Delay will not affect the opening of the 18.8 mainline miles of the facility.
- Contract for the I-95 collector/distributor system.

Contract E

- Request for Proposal; work under way.
- NTP scheduled for fall 2010; estimated completion date spring 2013.

Environmental Contracts

There are 51 environmental stewardship and mitigation projects; currently, 32 had at least reached completion of the concept phase.

Conclusion

This megaproject is currently in construction. There will be an operation phase managed by the owner, but there is nothing to report at this time for the operational phase. Among the many goals cited for the delivery method chosen, the preeminent reason was to save time (meet 4-year deadline imposed by the governor).

In terms of the dimensions contributing the most to project complexity, the project manager ranked the dimensions in the following order (the financial manager ranked the financing dimension fourth and the technical dimension as fifth but otherwise ranked them the same):

- Cost,
- Schedule,
- Context,
- Technical, and
- Financing.

In terms of the scale of complexity, all dimensions were given a relatively high complexity rating (85%) except for technical (55%). Many of the factors considered in each of the dimensions were considered to be complex (e.g., environmental, ROW) or considered a first for the agency (organizational structure, financing) but less complex or more standard particularly under the context and technical factors.

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