SHRP 2

STRATEGIC HIGHWAY RESEARCH PROGRAM

Accelerating solutions for highway safety, renewal, reliability, and capacity

Guide to Project Management Strategies for Complex Projects

S2-R10-RW-2

TRANSPORTATION RESEARCH BOARD

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THE SECOND STRATEGIC HIGHWAY RESEARCH PROGRAM

Guide to Project Management Strategies for Complex Projects

SHRP 2 Report S2-R10-RW-2

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TRANSPORTATION RESEARCH BOARD

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SUBJECT AREAS

Administration and Management
Construction
Highways

THE SECOND STRATEGIC HIGHWAY RESEARCH PROGRAM

America's highway system is critical to meeting the mobility and economic needs of local communities, regions, and the nation. Developments in research and technology—such as advanced materials, communications technology, new data collection technologies, and human factors science—offer a new opportunity to improve the safety and reliability of this important national resource. Breakthrough resolution of significant transportation problems, however, requires concentrated resources over a short time frame. Reflecting this need, the second Strategic Highway Research Program (SHRP 2) has an intense, large-scale focus, integrates multiple fields of research and technology, and is fundamentally different from the broad, mission-oriented, discipline-based research programs that have been the mainstay of the highway research industry for half a century.

The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life*, published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: Safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; Renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

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The members of the technical committee selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical committee and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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SHRP 2 STAFF

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Case study interviewees (by agency) were British Airports Authority; Caltrans; City of Saskatoon, Saskatchewan, Canada; Colorado DOT; Community Transportation Solutions; Connecticut DOT; FHWA; Florida DOT; Horner and Shifrin Engineers; Illinois DOT; KBR; Kentucky Transportation Cabinet; Maryland General Engineering Consultants; Maryland State Highway Administration; Michigan DOT; Missouri DOT; New Jersey Transit; New Zealand Transport Authority; North Carolina Turnpike Authority; Oklahoma DOT; Parsons Brinckerhoff; Texas DOT (Dallas District); Virginia DOT; Washington DOT; and Williams Brothers Construction Company.

Pilot workshops were held by Kansas DOT and Missouri DOT (Kansas City Workshop, March 2011) and Utah DOT (Salt Lake City Workshop, April 2011).

Validation case studies were conducted by Las Vegas Paving Corp. and Nevada DOT (I-15 South) and Iowa DOT (I-74 corridor).

Regional demonstration workshops were conducted by Caltrans, Colorado DOT, FHWA Resource Center (Craig Actis), Florida DOT, Institute for Transportation (InTrans), Iowa DOT, Michigan DOT, New York DOT, Ohio DOT, and Texas DOT.

FOREWORD

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The research scope of SHRP 2 Renewal Project R10, Project Management Strategies for Complex Projects, involved the development of this guide, as well as a companion report, surveys, case studies, training, and technical tools, to address the challenges of managing modern infrastructure projects that are considerably more complex than traditional projects. These products facilitate the use of effective strategies in managing complex projects of any size and type. Acceptance and use of this guidance should improve the state of the practice by focusing on practical tools and techniques that are designed to be immediately beneficial to transportation professionals.

Infrastructure needs within the United States have changed from building new facilities to replacing, expanding, and renewing existing facilities. The project management issues involved with infrastructure renewal differ from the project management issues for new construction. Correspondingly, new project management approaches must be integrated into mainstream practices for all sizes and types of projects to accelerate project delivery, reduce project costs, and minimize project disputes.

The difficulties of renewal project complexity have been exacerbated by years of underfunded maintenance and replacement programs. As a result, many renewal projects have become even more challenging because of the need to avert major traffic disruptions and, in some cases, infrastructure failures. Project complexity is introduced by many factors: project types, engineering complexity, size, modality, jurisdictional control, financing approach, contract type, and delivery method. Each project calls for a distinct project management style and approach.

The five-dimensional project management (5DPM) approach for complex projects is not new. However, it is extensively developed, outlined, and clearly mapped for acceptance and integration within the R10 project. The five dimensions are (1) cost,

(2) schedule, (3) technical, (4) context, and (5) finance. Successful use of the 5DPM approach involves five methods that are unique for each project:

- Define critical project success factors by each dimension, as required.
- Assemble project team.
- Select project arrangements.
- Prepare early cost model and finance plan.
- Develop project action plans.

Although a number of additional research ideas have been identified during the project, the most pressing next steps are the implementation of the material on actual complex projects and the integration of the philosophy and tools within existing agency program and project management policies and procedures. The integration will be accomplished through demonstration projects, training, and change-management assistance.

CONTENTS

1

FIVE-DIMENSIONAL PROJECT MANAGEMENT

1.1 WHO, WHAT, WHERE, WHEN, WHY, AND HOW

The objective of this guide is to assist transportation project managers and teams in delivering successful complex projects. This guide presents a practical approach or framework, as well as proven methods and tools tailored to rapid renewal of complex transportation project planning and management. The content comes from the in-depth study of 15 complex projects in the United States and three international projects that identified strategies, methods, and tools that led to the successful delivery of those projects.

The five-dimensional project management (5DPM) approach presented in this guide complements rather than replaces any agency's current project management practices and, as such, might add to or supplement the structure and practices of your agency's existing processes. Incorporating the methods, tools, and techniques presented in this guide is flexible and inherently dependent on the specific management and delivery needs of each particular agency on any particular project. Therefore, use of this approach (the methods, tools, and techniques presented) is fully scalable and may be as simple or as in-depth and extensive as needed or desired.

The major change from your regular or established project management process may be the focus and scope of planning tasks, with a strong emphasis on frontloading the project development process to identify and start addressing critical issues (including cost, schedule, technical, context, and financing issues) that create project complexity as soon as practical rather than later. Feedback from the participants in the pilot workshops, validation case studies, and regional demonstration workshops also indicated that implementation of the 5DPM approach could help bring more discipline to their own agencies' project development processes, resulting in improved project management.

The Benefits of the 5DPM Approach

The 5DPM approach represents an evolution in current transportation project management practices. Your project management team can apply this approach to highway projects of varying sizes and types to help identify, plan, and manage your projects proactively, reducing the schedule and cost impacts. This approach

- is scalable and adaptable to projects of all sizes and types—your complex projects do not need to be large or fit into the "mega" project genre to apply this approach;
- changes the context for projects from linear to dynamic by encouraging innovation and relational partnering and by emphasizing that each complex project has its own distinct set of critical success factors; and
- guides managers through a process to fully integrate teams across the entire complex-project life cycle, a practice that was determined to be a foundation for complex-project success.

Adapted from *SHRP 2 Solutions materials*

1.2 USING THE GUIDE

This guide provides a comprehensive manual for the 5DPM approach that transportation project managers and teams may use or incorporate and find beneficial in ensuring complex-project success. The guide includes details on the overall approach, the 5DPM methods, and 13 potential project management tools.

The guide can be used alone or as a supplemental, comprehensive reference for a training program that equips project managers and team members with the knowledge and tools needed for successful complex-project management. Live facilitated workshops are available through the second Strategic Highway Research Program (SHRP 2) Solutions Renewal Program and the Federal Highway Administration (FHWA) Office of Innovative Program Delivery. The training materials are available at www.trb.org/Main/Blurbs/167482.aspx.

Key references to other published material, research reports, training materials, and professional development classes on each of the specific methods and tools for managing complex projects are provided as additional resources throughout this guide.

The 5DPM approach is very amenable to self-implementation, and the SHRP 2 Solutions three-year implementation plan includes activities such as training, demonstration workshops, technical assistance, and peer exchanges to help you. Transportation stakeholders can participate in these activities to gain a better understanding of how to apply these project management concepts in their own project development process.

Adapted from SHRP 2 Solutions materials

1.3 5DPM PROCESS OVERVIEW AND GUIDE ORGANIZATION

The remainder of this chapter introduces the nature of project complexity, provides an overview of the five dimensions of complex-project management (referred to as 5DPM throughout this guide), and begins the discussion on implementation.

Chapter 2 delves into more detail about the three primary components of the 5DPM planning framework:

- Five (rather than the three traditional) project management dimensions;
- Five complex-project planning methods; and
- Thirteen complex-project management tools.

The second chapter outlines how the 5DPM approach overlays onto the typical project management phases for implementation and how your project management team assesses readiness to implement the 5DPM approach. It describes how the project team identifies, prioritizes, and quantifies the factors that create complexity in each dimension. Finally, it provides instructions for developing complexity maps that visually represent the scope and nature of project complexity.

Mapping complexity helps your project team to rationally allocate available resources and determine requirements for additional or specialized resources. Complexity maps also guide your application of the five complex-project planning methods (detailed in Chapter 3) and your selection of complex-project management tools (detailed in Chapter 4), as depicted in Figure 1.1.

Figure 1.1 shows three sequential phases from top to bottom:

1. **Project analysis.** The project team examines project complexity factors and develops the initial complexity map.
2. **Project planning.** Using the initial complexity map, the team begins to apply the five complex-project planning methods and may begin to develop the first nine sections of the FHWA project management plan (PMP) for major projects.
3. **Project implementation.** Based on the initial PMP, the team selects appropriate project management tools and details their application (in FHWA PMP Sections 10 through 22).

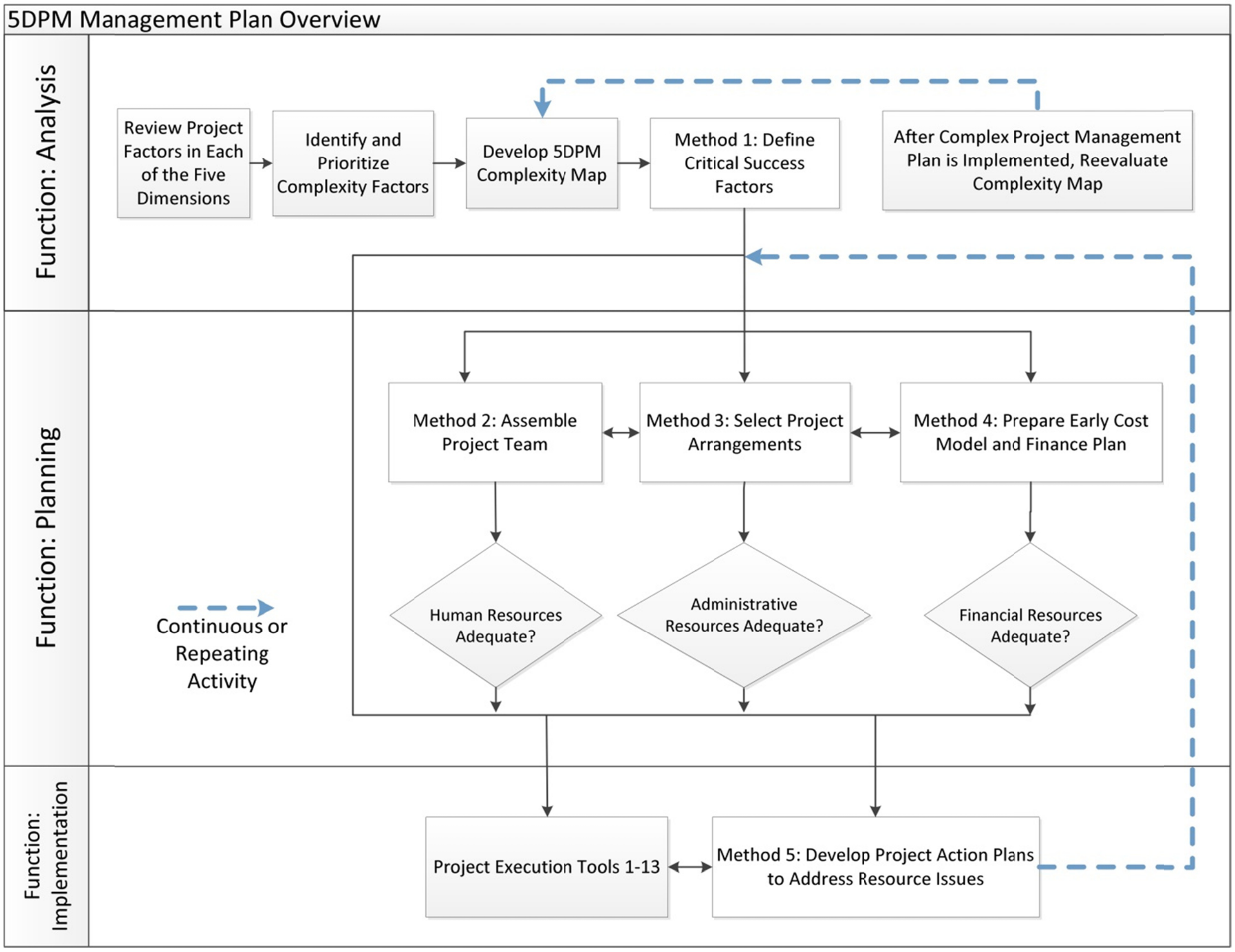


Figure 1.1. *Overview of complex-project management and 5DPM process flow.*

The result is an almost complete PMP for the complex project. Table 1.1 maps the contribution of 5DPM to the completion of the FHWA major project PMP development process and shows how the 5DPM process fits within the existing FHWA PMP process.

TABLE 1.1. HOW THE 5DPM PROCESS RELATES TO THE FHWA PMP PROCESS

FHWA PMP Sections	5DPM Methods and Tools
1. Project Description and Scope of Work	Initial Project Management Plan Development Meeting • Identify complexity factors • Prioritize complexity factors • Develop project complexity map
2. Goals and Objectives	Method 1. Define Critical Project Success Factors • Technical • Schedule • Cost • Finance • Context
3. Project Organization Chart, Roles, and Responsibilities	Method 2. Assemble Project Team • Disciplines • Limits of authority • Centralized or decentralized control • Additional resources
4. Project Phases 5. Procurement and Contract Management	Method 3. Select Project Arrangements • Office location • Limits of authority • Centralized or decentralized control • Additional resources
6. Cost Budget and Schedule	Method 4. Prepare Early Project Cost Model and Finance Plan • Inventory major features of work • Work breakdown structure • Milestone schedule • Initial cost estimate • Available funding • Additional financing required • Sources of additional financing
7. Project Reporting and Tracking	Method 5. Develop Project Action Plans • Technical issues • Schedule issues • Cost issues • Finance issues • Context issues
8. Internal and Stakeholder Communications 9. Project Management Controls	Method 5. Develop Project Action Plans • Technical issues • Schedule issues • Cost issues • Finance issues • Context issues
10–22. Additional PMP sections[a]	Tools 1–13 • Technical tools • Schedule tools • Cost tools • Finance tools • Context tools

[a] See *www.fhwa.dot.gov/ipd/project_delivery/tools_programs/project_management_plans/guidance.aspx*.

The major addition to the FHWA PMP process is the recognition in the 5DPM planning approach that a complex project involves managing numerous factors that are outside the project manager's direct control. Therefore, the PMP must identify and address external factors, such as public opinion and innovative financing, as early as practical. In addition, your project team must update your project complexity map regularly to ensure that the tools chosen to manage complexity are performing as planned in the PMP. If they are, the gross area of your project complexity map should shrink as complexities are managed successfully and the project proceeds as anticipated. The results of a carefully implemented 5DPM plan include successful project design and construction team integration from concept to completion. Integrated planning and execution with the resources needed is the 5DPM key to manage complexity successfully across the complex-project life cycle.

The third chapter of the guide details the use of each of the 5DPM methods. The fourth chapter details each of the 13 project management tools that you might employ on any given project.

The remainder of the guide includes glossaries of terms, references, and the following appendices:

A. Case Study Summaries

B. Project Complexity Survey, Ranking, and Scoring

C. Project Complexity Map (Radar Diagram)

D. Project Complexity Flowchart in Table Format

E. Project Management Tool Selection

1.4 NATURE OF PROJECT COMPLEXITY

Definition

Complex projects involve an unusual degree of uncertainty and unpredictability. The project manager must make decisions in an environment in which many of the critical factors are outside the project team's direct control. This situation leads to iterative planning and design to adjust the PMP to address seemingly random events that create unforeseen changes in the project's scope.

Project complexity is dynamic. Its components interact with each other in different ways, like pieces in a chess game. Although the project's ultimate scope may be uncertain in the early stages of project development, the project team must develop solutions to satisfy external stakeholders who can affect the agency's ability to achieve the complex project's objectives. The level of uncertainty may also vary with the maturity of the individual organization (CCPM 2006). Table 1.2 compares and contrasts traditional projects with complex projects.

TABLE 1.2. COMPARISON OF TRADITIONAL AND COMPLEX PROJECT CHARACTERISTICS

Traditional Projects	Complex Projects
• Standard practices can be used — Design — Funding — Contracting • Static interactions • High level of similarity to prior projects creates certainty	• Standard practices cannot be used — Design — Funding — Contracting • Dynamic interactions • High level of uncertainty about final project scope

The move to the 5DPM model for complex projects requires modifying traditional methods and implementing new project management tools and techniques. This guide provides a methodology that is based on the experience of seasoned complex-project managers and that draws from the study of the successful delivery of complex transportation projects.

Resource Commitments

Allocating resources to complex transportation projects requires a shift from traditional resource allocation models. With the traditional (noncomplex) project, the owner, designer, and builder assume duties in their customary disciplinary "stovepipes," and contracts govern collaboration among and coordination with other stakeholders. Complex projects require truly integrated delivery, making horizontal rather than vertical integration a key element of success.

In general, the owner, typically a state transportation agency, is responsible for managing the financing and funding and the contextual factors such as right-of-way acquisition; National Environmental Policy Act, National Historic Preservation Act Section 106, and Section 4(f) obligations of the U.S. Department of Transportation (DOT) Act of 1966; communication with local community groups; and so forth. The designer manages quality, compliance with codes and standards, and functionality. The builder is responsible for handling costs and schedules.

The primary responsibilities of the designer and builder form the "iron triangle" of quality, cost, and schedule. However, for complex projects, the uncertainty and dynamic interaction between the management activities of all project partners require that project management expand to a five-dimensional framework that elevates financing and context to the same level as the three traditional dimensions and changes the owner from an administrator to an active player with production responsibilities.

Renewal Projects

Transportation professionals recognize the uncertain condition of the nation's highway network and are actively searching for ways to deliver infrastructure projects "better, faster, and smarter." Because of the pressing need, one of the primary objectives of the SHRP 2 Renewal Program is to develop tools that help DOTs "get in, get out, and stay out." Project management is the catalyst that initiates the implementation of the various technical innovations developed through the SHRP 2 Renewal Program. The

January 2010 SHRP 2 Program Brief: Renewal states it this way: "Rapid renewal scenarios may require unusual project management practices and involve different risks and performance parameters. Renewal research is developing innovative strategies for managing large, complex projects, a risk management manual, and performance specifications that contribute to successful innovation" (SHRP 2 2010).

Randell Iwasaki, chair of the SHRP 2 Renewal Technical Coordinating Committee, furnished the following vision in the same program brief: "As the results of the SHRP 2 research are deployed, we will see more 'rapid renewal' tools developed for owners of the transportation system. The tools will lead to a fundamental change in how we approach rehabilitating our transportation system. We will be able to develop projects that are completed quickly, with minimal disruption to communities, and to produce facilities that are long lasting" (SHRP 2 2010).

Additional Programs Available to Facilitate Complex Renewal Project Delivery

Several established programs are available to facilitate the management of certain aspects of renewal projects. The guide, training, and other deliverables derived from the SHRP 2 R10 project are not intended to replace any other programs, but to complement them. The following descriptions are provided to assist in identifying other project management programs that may be beneficial.

Every Day Counts

In June 2010, FHWA added its unequivocal support to the national vision for rapidly renewing the highway system when it introduced its Every Day Counts initiative to address rapid renewal and other issues of similar importance. The Every Day Counts program is designed to accelerate the implementation of innovative practices that are immediately available, as described by FHWA Administrator Victor Mendez:

> Our society and our industry face an unprecedented list of challenges. Because of our economy, we need to work more efficiently. The public wants greater accountability in how we spend their money. We need to find ways to make our roads safer. And, we have an obligation to help preserve our planet for future generations. But, it's not enough to simply address those challenges. We need to do it with a new sense of urgency. It's that quality—urgency—that I've tried to capture in our initiative, Every Day Counts. (Mendez 2010)

Creating an atmosphere of urgency inside technocratic public transportation agencies is itself a challenge. Hence, the FHWA Every Day Counts (EDC) program focuses on proven innovations employed successfully by state DOTs: "EDC is designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment . . . it's imperative we pursue better, faster, and smarter ways of doing business" (Mendez 2010).

Accelerated Construction Technology Transfer

The Accelerated Construction Technology Transfer (ACTT) program brings national project management experts to the planning, design, and construction of major highway projects. A three-day ACTT workshop targets technical and administrative technologies that reduce construction time, save money, improve safety, and elevate quality. ACTT workshops result in a comprehensive analysis of the major project by transportation experts to identify solutions for the specific agency's complex-project goals.

Historically, highway renewal projects resulted in major traffic congestion in large urban corridors, angering the traveling public and increasing the pressure to "*get in*, *get out*, and *stay out*." The ACTT program focuses on achieving these objectives.

Highways for LIFE and Accelerated Bridge Construction

The FHWA Highways for LIFE program aims "to advance longer-lasting highway infrastructure using innovations to accomplish the fast construction of efficient and safe highways and bridges." The Accelerated Bridge Construction program is one of the most visible Highways for LIFE programs, acting as a platform for exchanging ideas and experiences among bridge owners, designers, and builders.

Accelerated Bridge Construction conferences typically attract DOT engineers, designers, suppliers, contractors, and academics, as well as federal, state, and local agencies. The conferences focus on prefabricated bridge systems and state-of-the-art lifting and hoisting equipment, advances in bridge materials, and innovative contracting methods that serve to shorten the time required for bridge construction. Minimizing traffic disruption, improving work zone safety, reducing environmental impacts, improving constructability, increasing quality, and lowering the life-cycle cost of bridges are the Accelerated Bridge Construction program goals.

Major Project Delivery Process

FHWA and state DOTs have a well-established process for planning major projects that includes risk management, National Environmental Policy Act processes, and financial planning. Transportation agency leaders and project managers must deal with many uncertainties when analyzing the allocation of highway appropriations; however, many uncertainties are quantifiable in terms of their probability of occurrence and impact of outcomes. Uncertainty is commonly termed risk. Risk analysis checks the cost-effectiveness of risk mitigation measures and forms the centerpiece of the FHWA major project delivery process.

However, for complex projects, risk evaluation must transcend traditional sensitivity analysis because critical input variables often have high degrees of uncertainty and vary in dynamic, interrelated ways. The major project delivery program advocates the use of probabilistic-based risk analysis, most often through a method known as Monte Carlo simulation.

Monte Carlo simulation uses probability distributions based on expert opinions or historical data. The output gives complex-project managers a better understanding of the relationships between cost and time uncertainties. This understanding helps project managers to determine which variables in the project have the greatest impact on achieving project cost and schedule objectives and to form risk mitigation plans.

1.5 TRADITIONAL COMPARED TO FIVE-DIMENSIONAL PROJECT MANAGEMENT

Traditional three-dimensional project management theory is based on optimizing the trade-offs between cost, schedule, and technical requirements (the "iron triangle"), as shown in Figure 1.2. Recent experience shows the increased effect that project context and financing have on design, cost, and schedule. Managing all these factors as separate and equal dimensions resulted in 5DPM. This section explains the development of the 5DPM framework.

5DPM extends traditional three-dimensional project management by adding the dimensions of context and financing, as shown in Figure 1.3.

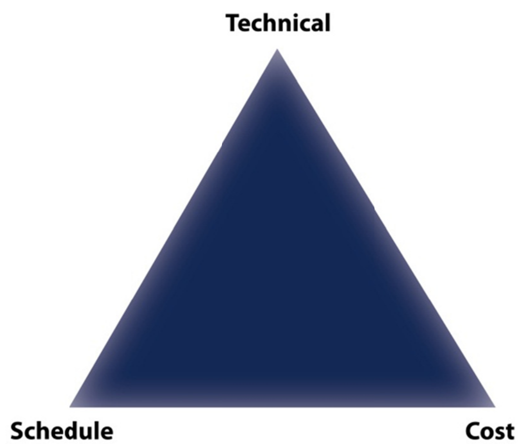


Figure 1.2. *Traditional three-dimensional project management.*

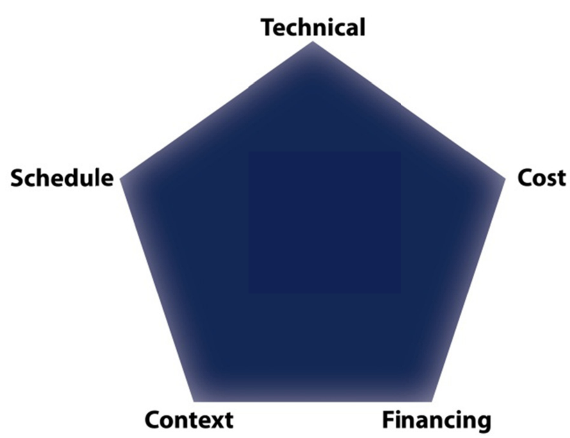


Figure 1.3. *Five-dimensional project management.*

The two new dimensions were identified from the analysis of the 18 case study projects examined in the research. This guide is a synthesis of the successful planning methods and management tools used to manage complexity found in the majority of those complex-project case studies. Appendix A offers details of the case studies that provided the information discussed in the guide.

The tools discovered in the research are organized around the five complex-project management dimensions. Therefore, developing the complex PMP using 5DPM starts with an inventory of the project requirements and the constraints associated with each dimension. By recognizing the project constraints at an early stage, the complex-project manager can gain input, support, and resources from affected stakeholders. The complex-project inventory uses the structure described in the next section.

1.6 DIMENSIONS OF 5DPM

This section provides an overview of the factors that make up 5DPM. The following list includes the factors that were found most commonly in the complex case study projects in each dimension of 5DPM, but it is not all-inclusive.

Dimension 1: Cost. The cost dimension comprises factors that quantify the scope of work in dollar terms:

- Project estimates;
- Uncertainty;
- Contingency;
- Project-related costs (e.g., road-user costs, right-of-way, railroads); and
- Project cost drivers and constraints.

Dimension 2: Schedule. The schedule dimension involves the calendar-driven aspects of the project:

- Time;
- Schedule risk;
- Prescribed milestones; and
- Availability of resources.

Dimension 3: Technical. The technical dimension includes typical engineering and design requirements:

- Scope of work;
- Internal structure;
- Contract;
- Design;
- Construction;
- Technology; and
- Nature of constraints.

Dimension 4: Context. The context dimension covers external influences that may have an impact on project progress:

- Stakeholders;
- Project-specific issues;
- Local issues;
- Environmental issues;
- Legal and legislative issues;
- Global and national issues; and
- Unexpected occurrences.

Dimension 5: Financing. The financing dimension involves understanding the impact of funding used to pay the project's cost:

- Public funding;
- Financing a future revenue stream;
- Exploiting asset value;
- Finance-driven project delivery methods;
- Financial techniques to mitigate risk;
- Differential inflation rates; and
- Commodity-based estimating.

Once the inventory and categorization of each project factor is complete, it is used like a risk register to generate the means and methods to deliver the project within its cost, schedule, technical, contextual, and financial constraints. Chapter 2 explains the 5DPM analysis and planning process in detail.

1.7 ORGANIZATIONAL IMPLEMENTATION APPROACHES

Overview

Without effective implementation, even the best process or practices with potential to bring significant benefits to your organization may remain just an idea or fizzle out with little success. A well-thought-out implementation plan using approaches to fit your organization's current culture, working environment, and complex-project management experience or maturity level is likely to be critical to the value of introducing the new process.

Although organizational change management was outside the scope of this research, we were asked to integrate 5DPM implementation into this guide to some extent and have done so in general terms without doing any benchmarking or research-based evaluation as part of the project. However, we have observed that strong, proactive leadership and support are essential until a new process becomes a regular business practice and that continuous monitoring and performance tracking of the new process are important for successful implementation. Clear communication with and training of the affected people and departments, both within and outside your organization, particularly in terms of potential benefits of the new process, anticipated changes, and required resources, are also essential. Figure 1.4 summarizes effective initial approach ideas to help start implementing the 5DPM approach.

Note that 5DPM implementation can be targeted to specific parts of any given program and that implementation can be piecemeal with a little at a time as needed or desired without a total overhaul of how you manage complex projects up front or at any given point in time.

Organizational Implementation Assessment

- Complex-project needs analysis
- Identification of goals and barriers
- Identification of affected people, departments, and processes
- Leadership and champion support needs and possibilities
- Realistic incremental change possibilities and pilot projects

Initial Implementation Action Plans

- Realistic implementation scoping and strategies, including resources
- Leadership buy-in and champion support plans
- Initial training needs and plans
- Awareness program plans
- Pilot project plans
- Feedback mechanisms
- Continuous process improvement plans

Figure 1.4 *Initial 5DPM implementation approaches.*

Establish Implementation Leadership

The most important element for successful implementation may be to establish strong implementation leadership. You might consider identifying and designating one or more champions and an implementation task force team or committee as the first step. Depending on your organizational structure (e.g., centralized versus decentralized), your implementation champions and task force team might be composed at the central agency level or at the district level.

Your task force team then becomes the vehicle to drive the 5DPM implementation process, from planning implementation activities to monitoring the performance of the new process. You will want your champions to be empowered to help with recruiting a task force, raising resources, increasing awareness, and other important tasks (CNCS 2013).

Your champion and task force team will need to secure strong support from top management because visible recognition and top-down support are keys to successful implementation of a new process. The task force that introduces and implements 5DPM can consist of an advisory board, technical advisory panel, and project team members.

You will want to recruit team members from all levels of your organization and actively involve them throughout your implementation process (Burke et al. 2001). This approach was used effectively by the Minnesota DOT when they formed a task force team to implement a new utility coordination process with representatives from various functional areas including utility agreements and permits, metro design, metro utilities, design, construction, land management, and others (Minnesota DOT 2006).

Develop Implementation Strategies and Put Plans into Action

Your implementation task force team needs to develop comprehensive strategies and plans that you deem to work well and fit well into your business practices and environment. The team brainstorms creative implementation ideas and includes these in your plans. Potential plans may include but are not limited to the following:

- Identification of affected people, departments, and processes;
- Organizational assessment;
- Awareness program;
- Pilot projects;
- Training;
- Barrier identification and plan of attack; and
- Performance evaluation and tracking.

Identify People, Departments, and Other Processes Affected

The 5DPM process can affect various departments and personnel, as well as other existing project management processes, within your agency. Your task force team needs to carefully identify all these impacts and develop mechanisms to promote and involve participation of all stakeholders (Minnesota DOT 2006). Your affected departments need to be ready to perform extra work resulting from the 5DPM approach or modify their current processes to support implementation.

You will need to set realistic, reasonable, and achievable expectations considering existing workloads. Additional personnel will need to be hired if required. In addition, you will need to clearly designate the individuals responsible for performing various tasks. Specifying expectations and responsibilities will be useful when other affected departments need to interact with the department in implementing the 5DPM process. Finally, any effect on the existing standards, specifications, and processes will need to be carefully considered, documented, and communicated (Iowa DOT 2006).

Assess Implementation Capabilities

Some 5DPM methods and tools might be new to your agency yet offer a powerful means to improve your capabilities to manage any given complex project. At the same time, a method or tool that you already use may be equivalent or superior to one of 5DPM methods and tools presented in this guide. Therefore, it may be beneficial to assess the experience, competency, or maturity level of your organization in terms of 5DPM implementation readiness. Your assessment results, as presented throughout this guide, may help you to use the 5DPM methods and tools strategically and selectively to augment your complex-project management capabilities. We recommend that you involve all stakeholders who will be affected by the 5DPM process in your assessment process.

Launch an Awareness Program to Communicate

The goal of an awareness program is to raise the collective awareness of a new process and its associated benefits and anticipated changes at the organizational level and beyond. Buy-in or getting others on board is critical, so you might want to look at your awareness program as a marketing strategy. The greater the exposure and involvement, the greater the level of acceptance and application. A successful awareness program calls for communication and engagement.

External stakeholders such as consultants and contractors who have worked with you in the past and those who might work with you in the future also need to be aware of any new process. You will want your task force team to identify available communication vehicles (e-mail messages, agency or departmental newsletters, agency websites, presentations, and so forth) to communicate and increase the collective awareness of the new 5DPM process. Given that people learn, seek information, and keep abreast of job-related changes in different ways, we recommend use of multiple outlets as part of an awareness program.

Conduct Pilot Projects

Your implementation task force team might find it beneficial to select a few pilot projects with different complexity factors before full-scale implementation of the 5DPM approach. Barriers to comprehensive 5DPM implementation, areas for further training and education, and needs for modification of the 5DPM process to fit into your business environment can be identified better or more clearly through pilot projects. You can develop appropriate 5DPM implementation plans for your agency by conducting and documenting pilot projects using one or parts of the approach.

Train the Right People

You will need to identify all the stakeholders within and outside your agency who will be affected by the 5DPM process so appropriate levels of training can be provided. The goal of training programs is to facilitate a more in-depth level of understanding for the 5DPM stakeholders and users. The organizational self-assessment results later in this guide will assist you in designing your training program by identifying the areas of 5DPM from which your agency can benefit.

Identify Barriers and Develop Plan of Attack

Your 5DPM task force team will find it beneficial to go through one or more brainstorming sessions to identify potential barriers to implementation of the approach and develop a plan of action to overcome those barriers. You might also want to conduct a survey of those affected to help identify barriers and solutions to the barriers. Input sources for identifying barriers could include organizational self-assessment results, pilot projects, and a performance evaluation process. We recommend documenting the barriers and following up until you can identify and execute clear solutions.

Establish and Conduct Performance Evaluations for Continuous Improvement

Performance measurement and tracking of a new process is another important aspect that you need to address. We recommend identifying measures of success up front before implementation. You can evaluate the new process on the basis of efficiency, productivity improvements, benefits to cost, return on investment, ease of use, and others. You can use questionnaires, interviews, observations, and so forth to evaluate process improvement and success. Make sure your evaluations also identify the specific limitations, problems, and barriers associated with the new process and recommendations for improvements.

Additional Resource

NCHRP Synthesis 355: Transportation Technology Transfer: Successes, Challenges, and Needs. 2005.

2 USING THE 5DPM PLANNING FRAMEWORK

2.1 IMPLEMENTING 5DPM

Section 1.7 discusses implementation approaches from an organizational leadership and strategy viewpoint, and this section presents an overview of implementation from a project management process viewpoint. Implementation of the 5DPM process aligns well with or overlaps the typical project development phases, as shown in Figure 2.1.

The typical project development process generally consists of six phases (planning; programming and scoping; preliminary engineering; final engineering; construction; and operation, monitoring, and maintenance), as shown in the left part of Figure 2.1. These phases often overlap as different parts of a project advance at different rates. Agencies may use different naming conventions for the phases or break some of them into more than one phase (such as a programming phase followed by a scoping phase).

As a project moves from planning to operation, monitoring, and maintenance of the facility (e.g., after construction obligations for some complex-project contracts), a number of different deliverables are developed, including the Highway Improvement Plan (HIP) and the State Transportation Improvement Plan (STIP), which represent the 10- and 5-year development and funding plans, respectively. The timing of these two plans can vary slightly from state to state (thus the spring representations in Figure 2.1). In addition, a variety of procurement options and decisions may take place on a complex project, including procurement of design services and construction services, at different points in project development.

As shown down the left side of the right part of Figure 2.1 (and covered in detail later in this chapter), complexity mapping occurs multiple times in the project development process to track the changes in project complexity. The project manager and project planning team identify success factors (Method 1) early in the project development process. Assembling the project team, selecting project arrangements, and

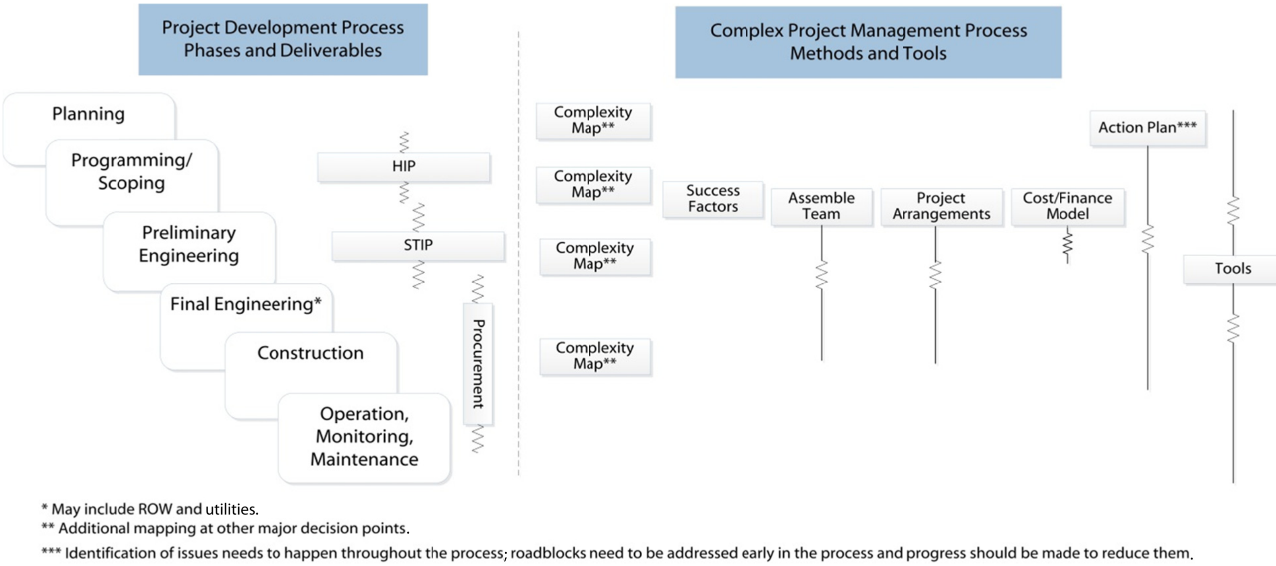


Figure 2.1. *Typical project development phases and deliverables (left) with 5DPM approach (right).*

developing a cost model and finance plan (Methods 2 through 4) happen concurrently, soon after identification of the critical success factors, and can be variable and revisited during further development of the project. The team starts developing project action plans (Method 5) almost at project conception and continues doing so throughout project development as needed. Finally, the team selects the tools appropriate for use, depending on project needs, throughout the project.

Table 2.1 shows when you are most likely to implement each of the 5DPM methods and 13 tools during each of the typical project development phases. The upper rows with darker blue shading and M in the table cells represent typical use of the 5DPM methods covered in this guide (Chapter 3), and the lower rows with lighter blue shading and T in the table cells represent typical use of the project management tools included in this guide (Chapter 4). Using the 5DPM methods, your team can select from the 13 project management tools to help achieve project success.

TABLE 2.1. IMPLEMENTATION MATRIX FOR 5DPM METHODS AND TOOLS BY TYPICAL PROJECT DEVELOPMENT PHASE

5DPM Method or Tool	Planning	Programming and Scoping	Preliminary Engineering	Final Engineering	Construction	Operation, Monitoring, and Maintenance
Methods						
1. Define critical project success factors	M	M				
2. Assemble project team	M	M	M	M		
3. Select project arrangements		M	M	M		
4. Prepare early cost model and finance plan		M	M			
5. Develop project action plans	M	M	M	M	M	
Tools						
1. Incentivize critical project outcomes	T	T	T	T	T	T
2. Develop dispute resolution plans		T	T	T	T	T
3. Perform comprehensive risk analysis	T	T	T	T	T	T
4. Identify critical permit issues		T	T			
5. Evaluate applications of off-site fabrication		T	T			
6. Determine involvement in ROW and utilities	T	T	T	T		
7. Determine work packages and sequencing	T	T	T			
8. Design to budget	T	T	T			
9. Colocate team		T	T	T		
10. Establish flexible design criteria		T	T			
11. Evaluate flexible financing	T	T	T			
12. Develop finance expenditure model	T	T	T			
13. Establish public involvement plans	T	T	T	T		

Note: ROW = right-of-way.

2.2 ASSESSING 5DPM READINESS

All transportation agencies have their own project development processes and various project management methods and tools. Some of the methods and tools presented in this guide might be new to your agency yet potentially powerful to improve or augment your existing capabilities to manage any given complex project.

We include a brief questionnaire with multiple-choice answers for each of the five methods and 13 project management tools detailed in the next two chapters to help you quickly and simply assess the experience, competency, or maturity level of your organization in using each of the methods or tools on any given project.

The questions to consider, which are covered in this guide, are as follows:

- When do we use these methods and tools during our project development process?
- How much experience, competency, or maturity does our agency currently have in any given area needed to manage a current or upcoming complex project successfully?
- How can we determine whether to implement any of these methods or tools?
- What actions do we take to implement any particular 5DPM method or tool?

Your quick assessments may help you to identify your risk level in implementing any particular method or tool on a project and may also help you to determine additional resources and organizational changes to consider in addition to use of this guide, as outlined in Table 2.2.

You might find it useful to go through all the quick assessments suggested in Table 2.2 to aggregate, as well as pinpoint, your current strengths and weaknesses and to help determine larger-scale potential needs, but doing so is not necessary to begin using this approach or parts of it on any given project. The 5DPM approach is flexible and overlays easily onto current transportation project management processes used across the country, so you can use it to introduce incremental changes and improvements to your own project management processes.

TABLE 2.2. 5DPM IMPLEMENTATION READINESS ASSESSMENTS AND RECOMMENDATIONS

Readiness	Definition	Description	Recommendations
Novice	No project management controls applied or considered.	You view your agency's project management maturity or experience level at the lowest level for implementation of this 5DPM method or project management tool, with little or no prior experience using it.	Beginning with this complex project, consider a targeted training program in addition to use of this guide and the training materials available on this project to establish a standard process for continuous project management use and improvement. Also, survey the additional resources annotated in the guide and training materials to help meet your needs.
Above novice	No formal process, established tool, or designated staff, with ad hoc methods applied by a few specialists.	You view your agency's project management maturity or experience level fairly low for implementation of this 5DPM method or project management tool, although you may have had some prior experience using it on an ad hoc basis without any established process.	Beginning with this complex project, consider a targeted training program in addition to use of this guide and the training materials available on this project to establish a standard process for continuous project management use and improvement. Also, survey the additional resources annotated in the guide and training materials to help meet your needs.
In-between with buy-in	Basic process and tools used repeatedly but not standardized and/or management practices vary from project to project.	Your agency recognizes the need to use this 5DPM method or project management tool but currently has little experience using it or has a loosely defined process, if any.	Beginning with this complex project, consider a targeted training program in addition to use of this guide and the training materials available on this project to establish a standard process for continuous project management use and improvement. Also, survey the additional resources annotated in the guide and training materials to help meet your needs.
Some maturity or experience	Standard organizational process, methods, tools, and staff are established and documented.	Your organization has some experience with, and an established process for, use of this 5DPM method or project management tool.	You may want to incorporate a feedback (lessons learned) loop into your current process by collecting and analyzing the relevant information after project completion for continuous improvement. Your agency may want to refine your current process by reviewing the related 5DPM methods and tools in this guide as well as the available training materials. Also, survey the additional resources annotated in the guide and training materials to help meet your needs.
Mature or experienced	Performance management is enabled by quantitative feedback with lessons learned and best practices applied for continuous process improvement.	Your agency is highly mature or experienced in implementing this 5DPM method or project management tool.	You may want to refine your current process by reviewing the related 5DPM methods and tools in this guide, as well as the available training materials. Also, survey the additional resources annotated in the guide and training materials to help meet your needs.

2.3 DEFINING PROJECT COMPLEXITY

When implementing the 5DPM approach on a project to help manage project complexity, it is important to standardize and focus on each of the five dimensions to ensure the following:

- Every member of the project team understands and uses the same terminology in the same fashion.
- External stakeholders understand the meaning of the terminology used in conjunction with the complex-project management documents.
- Each factor is categorized under a single project management dimension where it can be further associated with specific management tools and assigned to project action plans for mitigation or resolution.
- Consistency is maintained in the project record to make it fully useful on an ongoing basis and as an example for future complex-project management plans.

The five dimensions are defined below.

Dimension 1: Cost

The focus on the cost dimension covers the factors that affect quantifying the scope of work in dollar terms. You can use the following list as a cost dimension performance standards checklist:

- Document the overall project scope.
- Communicate the estimator's knowledge of the project by demonstrating an understanding of scope and schedule as it relates to cost.
- Alert the project team to potential cost risks and opportunities.
- Provide a record of key communications made during estimate preparation.
- Provide a record of all documents used to prepare the estimate.
- Act as a source of support during dispute resolutions.
- Establish the initial baseline for scope, quantities, and cost for use in cost trending throughout the project.
- Provide the historical relationships between estimates throughout the project life cycle.
- Facilitate the review and validation of the cost estimate (AACEI 2010).

Note that the second checklist item relates cost to scope and schedule. In 5DPM, cost relates to financing and context as well as schedule and scope. Table 2.3 provides a synopsis of the factors to consider in the cost dimension and includes applications and examples.

TABLE 2.3. COST DIMENSION FACTORS

Factor	Definition	Application	Example
Project estimates	Involves all types of cost estimates completed throughout the project life cycle.	Team members and their roles are identified, which requires that all project delivery team members be aware of and provide input to the estimating process.	Structural designer verifies the number of tons of steel used in the estimate and advises project manager on potential quantity growth as the design advances.
Uncertainty	Distributes risk in the 5DPM plan and then quantifies that risk within the estimate.	• Meet project objectives, expectations, and requirements. • Facilitate an effective decision or risk management process. • Identify risk drivers with input from all appropriate parties. • Link risk drivers and cost or schedule outcomes. • Avoid self-inflicted risks. • Employ experience or competency. • Provide input for probabilistic estimating results in a way that supports effective decision making and risk management (AACEI 2008).	Risks faced in a complex project, especially if the agency is implementing a new technology such as Accelerated Bridge Construction methods or a new delivery method such as public–private partnerships.
Contingency	A method that quantifies the risk in a cost estimate.	Insurance, bonding, outsourcing, and project reconfiguration are used to eliminate a specific risk (e.g., changing the project alignment to avoid a thorny ROW acquisition issue).	Developing contingencies such as adding float in the budget for line items that are thought to be potentially problematic. Methods for developing contingencies include probabilistic estimating, sensitivity analysis, Monte Carlo simulations, and a spreadsheet-based application suite for predictive modeling.
Project-related costs	Costs borne to complete the project but that may not be financed with project funding.	Agency soft costs for personnel, facilities, and administrative overhead.	The costs of overtime for in-house employees due to loss of a specific group of personnel dedicated to work on the complex project only.
Project cost drivers and constraints	The technical aspects of a complex project that define its scope in terms of the cost to deliver it.	When a complex project has a finite amount of financing and no ability to change the budget as circumstances change, managing the cost dimension becomes a zero-sum game. This makes it critical to identify those features of work that drive the final cost of the project.	The dimensions of the pavement section for an urban Interstate highway reconstruction project are driven by traffic and project length; thus, pavement costs drive the cost.

Dimension 2: Schedule

The focus on the schedule dimension relates to all the calendar-driven aspects of a complex project. The schedule dimension furnishes the time factors necessary to achieve delivery of the complex project by the time they need to be resolved. The purpose for documenting the background and rationale used to develop complex-project schedules can be summarized as follows:

"By documenting the schedule basis, the project team captures the coordinated project schedule development process, which is by nature unique for most construction projects. This improves the final quality and adds value to the project baseline schedule, which serves as the *time management navigation tool to guide the project* team toward successful project completion. The schedule basis also is an important document used to identify changes during the schedule change management process" (AACEI 2009, italics added).

The term *tool* highlights that coordinated scheduling facilitates time and cost management and ultimately the quality of the completed project. Complex projects are often delivered at a faster pace than routine projects. Therefore, it is imperative that the delivery schedule accurately reflects the relationships between activities to mitigate potential delays. Table 2.4 summarizes the factors to look at in the schedule dimension and includes applications and examples.

TABLE 2.4. SCHEDULE DIMENSION FACTORS

Factor	Definition	Application	Example
Time	The period in which the complex project must be delivered.	• Scope of work • Work breakdown structure • Key assumptions and constraints • Sequence of work • Key project dates • Critical path • Schedule inclusions and specific exclusions • Schedule change order process • Integration and progress-reporting process • Key procurements and submittals (AACEI 2009)	The amount of time that must be allocated to obtaining NEPA clearance.
Schedule risk	Risk associated with a project that cannot be clearly identified and quantified through formal or informal methods.	Schedule contingency: • Number of time units (e.g., rain days, stand-by days), or • Amount of money that represents the cost of mitigating the given risk.	A contingency earmarked to pay premium wages to the workforce to recover the schedule in the event of a delay (sometimes called a schedule reserve or time allowance).
Prescribed milestones	Key project dates set for intermediate progress points that mark the start and finish of portions of the complex project.	Milestones consist of events "such as the project start and completion dates, regulatory/environmental key dates, and key interface dates . . . planned turn-around/shut-down dates, holiday breaks [and] key procurement mitones/activities" (AACEI 2009).	Key submittals, such as permits or key project quality assurance "hold points," inspections, or both.
Resource availability	Availability of the necessary personnel, equipment, materials, and financial resources to be able to maintain the production rates used in developing durations for the activities in the complex-project schedule.	The project's resource profile should separate critical resources from noncritical resources; critical resources are resources that are doubly constrained (e.g., only available in a finite quantity during a specific period).	A specialized piece of equipment that is the only piece of that size or capacity in the region; must be booked in advance; and, once booked, is only available during the booking period.

Note: NEPA = National Environmental Policy Act.

Dimension 3: Technical

The focus on the technical dimension fleshes out all technical aspects of the project, including the typical engineering requirements. Issues for this dimension include design requirements, scope of the project, quality of construction, and the organizational structure of the owner or agency undertaking the project. The technical dimension also includes items such as contract language and structure and the implementation of new technologies for effective management of the project. Table 2.5 spells out the factors associated with the technical dimension and includes applications and examples.

TABLE 2.5. TECHNICAL DIMENSION FACTORS

Factor	Definition	Application	Example
Scope of work	The purpose of the project that technically defines the constructed facility to satisfy that purpose.	An inventory of all the primary and ancillary technical features of design and construction work.	The as-planned scope of work must exactly match the as-designed scope of work and, in federal-aid projects, this process must also review the scope for features of work not authorized in the project funding documents, as well as in the NEPA clearance.
Internal structure	How the owner or agency is organized (e.g., traditional hierarchy, matrix with project teams) to manage the complex project effectively.	The form and composition of the project team should be based on the integration of the oversight, design, and construction teams, which are based on the chosen project delivery method, where design–bid–build represents the need for minimal integration and construction manager–general contractor represents maximum integration.	In many cases, achieving maximum integration requires colocation of the design team, agency oversight team, and construction team; typically, colocation means sharing office space on the project site to facilitate immediate joint reaction to issues and over-the-shoulder reviews of the design product.
Contract	The main legal documentation between the owner or agency and its project partners.	• Prequalification • Warranties • Dispute resolution measures	Extended warranties provided by contractors to ensure quality and guarantee pieces of the project will perform satisfactorily for a specified period.
Design	Different aspects include method, reviews and analysis, and existing conditions.	Agency policy for planning and design development.	Reviews and for maintaining accuracy and quality of the design, such as value engineering analysis and constructability reviews.
Construction	Quality, safety and health, optimization, and climate impact.	Agency policy for construction delivery.	A complex project in a northern state will need to use means and methods that permit all weather-sensitive work to be completed during the typical construction season.
Technology	Complex project's need to leverage technology to facilitate design, construction, or operational requirements.	• Three-dimensional design systems • Construction automation • Project communications • Project management software • Project information modeling • Intelligent transportation	Global positioning system–enabled or machine-guided construction equipment used to minimize the need for land surveyors during construction.
Nature of constraints	Complexity created by project extremes.	Early recognition of project constraints is a critical factor in understanding and managing complexity.	Extremes may include the following: • Skewed alignment • Extreme topography • Narrow corridors • Zero backwater rise

Note: NEPA = National Environmental Policy Act.

Dimension 4: Context

Focusing on context as a separate project complexity dimension helps manage all external factors that have an impact on the project. Context factors can be some of the most difficult to predict and manage before and during construction. Context includes stakeholders, environmental issues, legal and legislative requirements, local issues, and project-specific factors. Table 2.6 defines the factors typically associated with the context dimension and includes applications and examples.

TABLE 2.6. CONTEXT DIMENSION FACTORS

Factor	Definition	Application	Example
Stakeholders	Parties directly affecting, and affected by, the project	• Public relations planning • Permitting • Training for internal staff	The public, politicians, owner or agency, and jurisdictional stakeholders.
Project-specific issues	Factors that directly relate to the complex project	• Maintaining capacity • Work zone visualization • Intermodal requirements • Utility issues	Work zone visualization maintains capacity by using various means to alert the public to change in normal traffic routes.
Local issues	Factors that are specific to the affected community	• Social equity studies • Demographics • Public services • Land use • Growth inducement • Land acquisition • ROW acquisition • Economic impact • Marketing • Cultural sensitivity • Workforce	A new highway project running through a low-socioeconomic neighborhood could displace residents without the means to relocate. Conversely, a new project could produce a growth inducement, increase land use, and improve the area's economy.
Environmental conditions	Self-explanatory	• Commitments made to obtain permits • Special ecological issues • Sustainable design	Designing a pavement that maximizes the use of recycled materials from the project itself.
Legal and legislative requirements	Local procurement law and local industry and internal staff acceptance	• Enabling legislation for alternative delivery • Industry bidding culture • Availability of sophisticated design consultants and construction contractors	Industry outreach sessions to collect potential issues that might act as a barrier to receiving enabling legislation.
Global and national conditions	Events that occur outside the region that affect the complex project	• War • Commodity shortages • Labor strike among material suppliers • Natural disasters	Hurricane Katrina created a shortage of sheet piling in its aftermath, causing many projects to be delayed pending availability of that material.
Unexpected occurrences	Self-explanatory	• Unusually severe weather • Force majeure	Catastrophic weather events, wildfires, earthquakes, and delays and damage due to terrorism.

Dimension 5: Financing

Focusing on financing as a separate project complexity dimension is increasingly important because, for complex projects, it is no longer sufficient to merely know the project cost. The owner must know how the project will be paid for and integrate that knowledge into the scope of work. The mechanics of financing can have a direct impact on the project design, the speed with which the project is delivered, and the ability to achieve contextual requirements.

> "As public funds become insufficient to provide for timely renewal of the nation's infrastructure in the traditional pay-as-you-build model, innovative funding and the injection of private capital into traditionally public financing arrangements have added new modes of complexity to projects."
>
> *R. J. Tetlow (2007)*

Traditional three-dimensional project management assumes that the cost of the project is a direct function of its technical requirements. Therefore, designers work on the principle that the agency must find the money to fund the project and, the design, itself, will define project budget and schedule.

Complex projects often reverse that principle. Many complex projects need the financing arranged in conjunction with the design process. Therefore, available financing materially drives the features of work that result in the final design. This approach shifts the focus away from how much money is needed to deliver the desired capacity to how much capacity can be delivered for the available financing. If the scope is not flexible for modification, then additional revenue or financing capacity needs to be rigorously identified for project authorization. Table 2.7 defines the factors to consider in the financing dimension and includes applications and examples.

Finance Dimension Resource

Because of the varied nature of innovative and experimental financing policies potentially available for transportation agencies to leverage for complex projects today, it is difficult to differentiate and categorize the methods. The methods frequently become so project-specific that any attempt to develop a precise yet general definition is probably impossible.

For more in-depth knowledge of emerging thought on project finance and program policies, the U.S. Congressional Budget Office has released a detailed study of the financing issues for complex projects titled *Alternative Approaches to Funding Highways* (https://www.cbo.gov/ftpdocs/121xx/doc12101/03-23-HighwayFunding.pdf).

TABLE 2.7. FINANCING DIMENSION FACTORS

Factor	Definition	Application	Example
Public funding	Traditional sources of funding for public projects	• Federal-aid funds • State funds	Advance construction that "allows a state to begin a project even if the state does not currently have sufficient federal-aid obligation authority to cover the federal share of project costs" (FHWA 2002).
Bond and debt financing	Methods to access capital markets	Capital cost financed using some type of bond, and the revenue generated by the facility used to retire the debt over a specified period. • Size of bond fixed with an early cost estimate • Bond issue creates a fixed delivery schedule to service debt • Postconstruction revenue estimates • Actual traffic growth versus estimated growth	Grant anticipation revenue vehicles (GARVEEs), private activity bonds (PABs), Build America Bonds (BABs), and so forth.
Loans and credit assistance	Direct loans from the federal government or improved credit	Help state or project sponsor to obtain loan directly from the federal government or tap into the capital market at a lower interest rate with the federal government's credit assistance.	Transportation Infrastructure Finance and Innovation Act (TIFIA), state infrastructure banks, and so forth.
Exploiting asset value	Using an existing asset to create new revenue	• Monetizing • Franchising • Carbon credit sales	• Leasing a bridge to a private company to gather toll revenue. • Developing Interstate rest areas with food or fuel concessions. • Leveraging a greenbelt to create securities that are salable on the Chicago Climate Exchange.
Finance-driven project delivery methods	Project delivery methods such as public–private partnerships in which financial considerations are a major part of the delivery process.	Give public agencies access to private capital and thus accelerate the delivery of its service to the traveling public.	Unsolicited comprehensive development agreements to build a new bridge or road.

Additional Resources

FHWA and SHRP 2 have many resources available to assist complex-project managers in analyzing project needs. The FHWA Office of Innovative Program Delivery website is a good resource (www.fhwa.dot.gov/ipd/index.htm). SHRP 2 Highway Renewal products can be accessed at www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Renewal_156.aspx.

2.4 MAPPING PROJECT COMPLEXITY

To map project complexity, the project manager and project planning team must define and understand the factors affecting complexity, as outlined earlier in this chapter. Mapping project complexity will help you to identify, understand, and rank the critical project success factors.

> "The definition of successful transportation project management is expanding to include broad, holistic, and long-lived measures of project performance."
>
> *K. Jugdev and R. Muller (2005)*

The subsequent steps involve allocation of administrative, human, and financial resources to the project (these methods are described in detail in Chapter 3). If the resources necessary to successfully manage the project are inadequate or are constrained by outside factors, you will need to develop project action plans to mitigate, eliminate, or resolve the inadequacies and constraints.

The final steps in the 5DPM process will be to select appropriate project management tools (described in detail in Chapter 4). The steps are discussed in increasing detail in the following sections and in Chapters 3 and 4.

Early in the project planning stages, the project leadership team analyzes the factors of complexity in each of the dimensions. The complexity survey in Appendix B will help the team analyze project complexity. Project leaders should feel free to add other factors not contained in the survey to better model a given project's unique complexity profile. Once complete, all team members must understand the team's definitions for each factor and generally agree on the sources and nature of complexity on the project.

This section discusses the development of 5DPM complexity maps, which help project teams to understand and define the dimensions of their project complexity and to allocate resources and select tools. The team scores each dimension of complexity on a scale from 0 to 100 (see Figure 2.2 and Part VII, No. 2 of Appendix B).

	Scale				
Cost Dimension Complexity	Minimal		Average		High
	0	25	50	75	100
	Scale				
Schedule Dimension Complexity	Minimal		Average		High
	0	25	50	75	100
	Scale				
Technical Dimension Complexity	Minimal		Average		High
	0	25	50	75	100
	Scale				
Context Dimension Complexity	Minimal		Average		High
	0	25	50	75	100
	Scale				
Financing Dimension Complexity	Minimal		Average		High
	0	25	50	75	100

Figure 2.2. *Scale for scoring project complexity by dimension.*

Note that it is much less important for the team to agree on absolute scores than on relative scores (from one dimension to the other). In other words, the relative order of the scores (from 0 to 100) should match the rank order of dimensions from least to most constrained (as shown in Part VII, No. 1 of Appendix B). After averaging or agreeing on the score to assign to each dimension's complexity, project complexity mapping can begin.

The dimension that represents the highest combination of complexity and constraint most likely presents the greatest challenges on the project and therefore requires the most management attention. In addition, complexity is frequently created by the interaction between dimensional factors, and this interaction provides an opportunity to apply innovative solutions to the least-complex or least-constrained dimensions and mitigate the impact of the most-constrained and most-complex dimensions.

To map project complexity, create a spreadsheet with two columns as shown in Figure 2.3 (and in Appendix C).

Dimension	Score (0-100 from VII.2)					
Technical						
Cost						
Financing						
Context						
Schedule						

Figure 2.3. *Complexity mapping spreadsheet template.*

The first column in the spreadsheet contains the names of each of the five complexity dimensions, and the second column contains the complexity score for each of the dimensions (0 to 100) for the project. The scores for each dimension are charted, using the Radar Chart feature in Excel, for example, as shown in Figure 2.4 (and in Appendix C).

Dimension	Score (from VII.2)
Technical	70
Cost	90
Financing	50
Context	60
Schedule	80

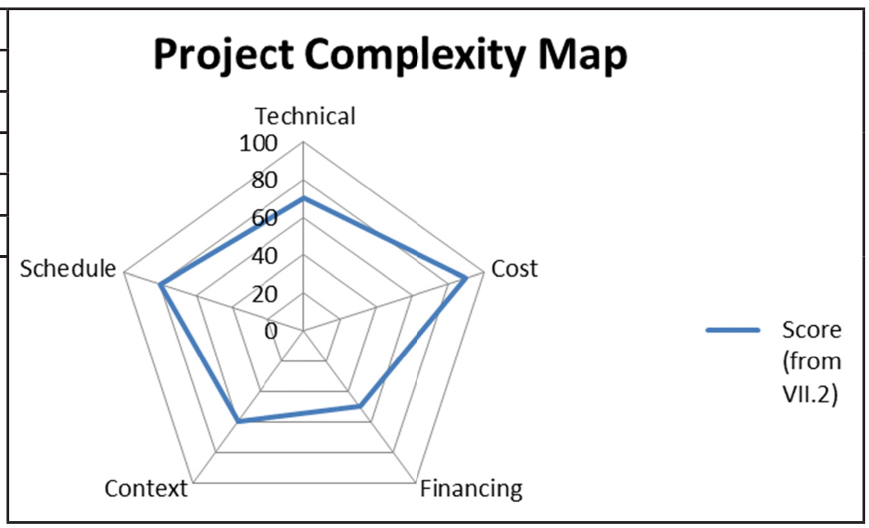


Figure 2.4. *Example of radar complexity map based on scores for the five dimensions.*

Based on the five dimensions, the resulting pentagon provides a graphic depiction of both the overall complexity of the project (area of the pentagon) and the specific nature of the complexity (the skew of the pentagon), as the example in Figure 2.4 illustrates.

This guide shows how complex projects need to be managed from conception through execution. The dynamic interaction of the dimensions and use of the 5DPM methods and tools should result in changes in the complexity map as your project progresses. Managing complexity does not stop during the project and requires continual monitoring and project mapping iterations.

2.5 LEVERAGING ITERATIVE PROJECT MAPPING

Project complexity is dynamic rather than static, and the relative complexity of each dimension changes as the project matures. Once a given element of complexity is effectively addressed, the complex-project manager needs to shift attention and resources to the next critical factor of complexity. Consequently, the mapping process needs to be revisited periodically during the project as a tool for refocusing the project team on the factors most in need of resourcing to continue progress toward achieving project objectives.

The complexity map is a visual project-control metric. Given the dynamic nature of project complexity, the area of the resulting pentagon is a means to measure current project complexity at any given point in time. In theory, as a project progresses toward successful completion, complexity shrinks and the area on the map is reduced.

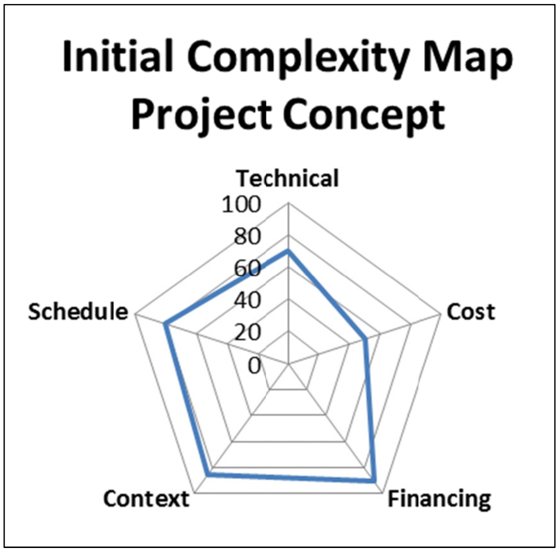
Figure 2.5 shows how a complexity map for a hypothetical complex project changes over time.

The initial complexity map was created at the project concept stage. This map shows that financing was the most complex dimension, followed by context and schedule.

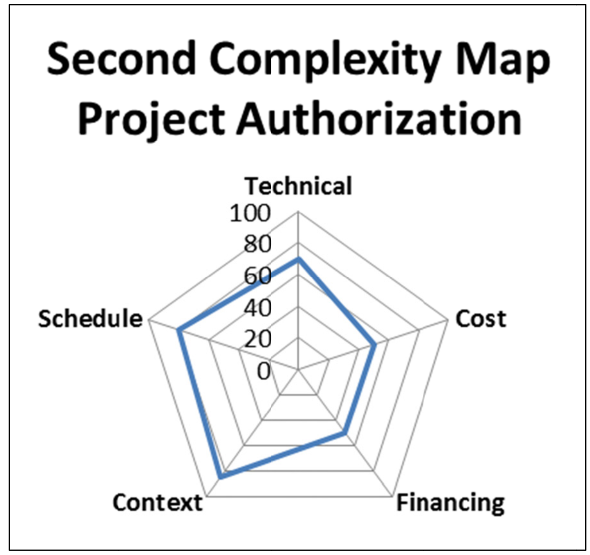
The second complexity map was created at project authorization. It shows that, in the intervening period, the project team had successfully addressed the financing dimension, making context the most complex dimension.

The third complexity map illustrates the complexity at the point when design and construction can begin. By this time, most of the context dimension factors have been dealt with, and the technical and schedule dimensions are the remaining dimensions that require adequate resources for a successful project. Note that the area of the resultant pentagon was reduced by nearly half because of the endeavors of the project team to address complexity in the previous phases.

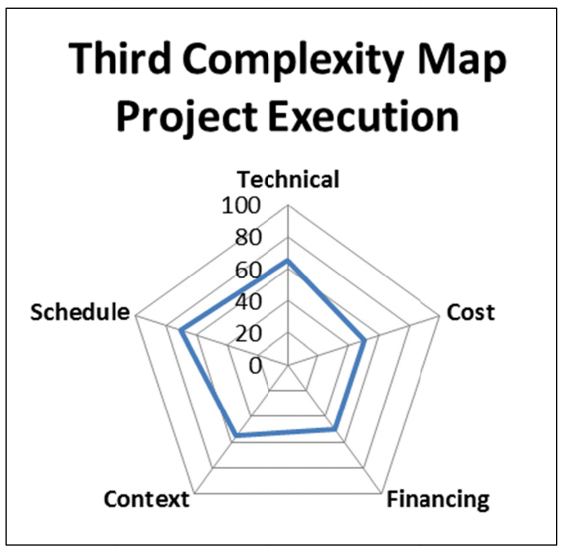
One additional point deals with the changing composition of the project team. Although the complex-project manager and other key individuals should remain with the project throughout its life cycle, the next layer of personnel will probably change as the project moves from planning to design to construction.



(a)



(b)



(c)

Figure 2.5. *Sample project complexity map changes over time: (a) project concept, (b) project authorization, and (c) project execution.*

Each discipline has its own unique view of project complexity that is a function of its expertise and ability to understand other disciplines' roles in the project. Therefore, as the project complexity map is revised over time, it remains important for project team leaders to consistently score current complexity in each dimension on the basis of input from the other team members who are engaged decisively in the current project requirements.

Reevaluation of the mapping of the project is important because new or different factors will have more impact as the project develops. In addition, as discussed in the next section, the footprints of complexity maps can be compared across projects to identify the nature of complexity and make appropriate resource allocations.

2.6 ALLOCATING RESOURCES TO COMPLEX PROJECTS

Project complexity maps are useful (and powerful) tools for organizational leaders in assigning internal team members, developing effective procurement plans, advocating for project needs to state legislators and policy makers, and allocating financial resources effectively. Fundamentally, complexity maps elevate the visibility of the most critical dimensions at the earliest opportunity, so the project manager can identify and allocate resources for possible complexity solutions.

The primary objective is to do as much early planning as required, rather than waiting for a particular phase of project development to identify and resolve issues. The Virginia DOT I-95 James River Bridge project is an excellent example of how this practice is implemented.

Early Planning Example: Virginia DOT I-95 James River Bridge Project

The critical success factor in the James River Bridge project was to minimize congestion on I-95 in downtown Richmond during construction. The Virginia DOT determined that to achieve this outcome, they needed to reduce the average daily traffic by approximately 50%. The project management tool they developed to deal with this aspect of complexity was to hire a public relations firm before design started to initiate a 2-year targeted public information effort that encouraged motorists and, more significantly, trucking companies, to self-detour.

The effort was successful, largely because the project manager did not wait for the technical dimension of the project to be well defined and allocated appropriate resources (in this case, the public relations consultant) to deal with the context dimension during the planning, rather than the design, phase.

Mapping project complexity for resource allocation furnishes a rational method with which to justify the need for additional resources. For instance, a typical DOT does not usually have engineers on staff with sophisticated knowledge and experience with innovative financing. Thus, identifying the financing dimension as the most complex forces the project manager to look for a resource to manage that dimension, and if it does not exist in house, the wheels can be set in motion to procure that expertise from outside the agency.

The process used to identify a dimension as critical produces documentation that you can use to justify the expenditure of early resources internally in your agency, as well as externally to state legislators, highway commissioners, and the like. This guide's foundational research clearly demonstrates that complex-project success is directly tied to timely allocation of required resources to service the dimensions with the most critical complexity.

2.7 UNDERSTANDING THE INTERACTIONS OF COMPLEXITY FACTORS

In addition to being dynamic, the project dimension factors are often interrelated, although they are treated as exclusive to each dimension in complexity mapping. Project teams need to identify and understand the interactions between the complexity factors early in project development to aid in understanding and managing complexity and working through the methods, associated resource allocation, and selection of tools.

To begin to understand the interactions, the project team can determine if each of the factors identified in complexity mapping is a roadblock (an absolute or fixed constraint that will prevent using needed innovations to achieve success) or a speed bump (a significant challenge that might impede project success but that has alternative solutions).

If, for example, an infrastructure project has a critical, fixed completion date (e.g., the 2002 Olympic Games' impact on the I-15 project in Salt Lake City, Utah) or critical interim milestones (e.g., coordinated ramp openings and closings), the project team must be innovative in creating flexibility in as many other complexity factors as possible. For example, if the completion date is fixed and critical, then the cost, design, financing, and context issues should be addressed with flexibility in mind (e.g., innovative financing, design exceptions, incentive contracts, and early stakeholder involvement).

If more than one complexity factor is fixed, the need for flexibility and innovation in the remaining factors increases. As a hypothetical case, if a long-span bridge must accommodate dual barge traffic with zero backwater rise (technical complexity) and has a fixed, expiring appropriation with a critical completion date (financing and schedule complexity), the project team should work closely with influential stakeholders to create innovative solutions to cost and context issues.

The interactions can be communicated in a table format as shown in Table 2.8 (with instructions and a sample table template in Appendix D). This table can be used to help identify the critical inputs to the project development methods (Chapter 3) and the appropriate selection of project management tools (Chapter 4).

TABLE 2.8. SAMPLE PROJECT COMPLEXITY FACTOR TABLE FOR CONSTRAINTS AND INTERACTIONS

	Most Complex →				Least Complex
Dimension	**Schedule**	**Technical**	**Cost**	**Context**	**Financing**
Complexity Factor	Expiring appropriation (constrained)	Dual barge traffic (constrained) Zero backwater rise (constrained)	Uncertainty over how to phase the project (flexible)	Downtown business leaders would prefer signature bridge (flexible)	XXX (flexible)
Interaction	Driver	Interacts with schedule	Interacts with schedule	Interacts with schedule, cost, and technical	Interacts with XYZ

2.8 CONNECTING THE 5DPM FRAMEWORK TO COMPLEXITY ON YOUR PROJECT

Figure 2.6 encapsulates the relationship of the factors within each of the five dimensions of project complexity (listed across the top of the figure) to the project analysis and planning methods, which are listed on the far-right side of the figure.

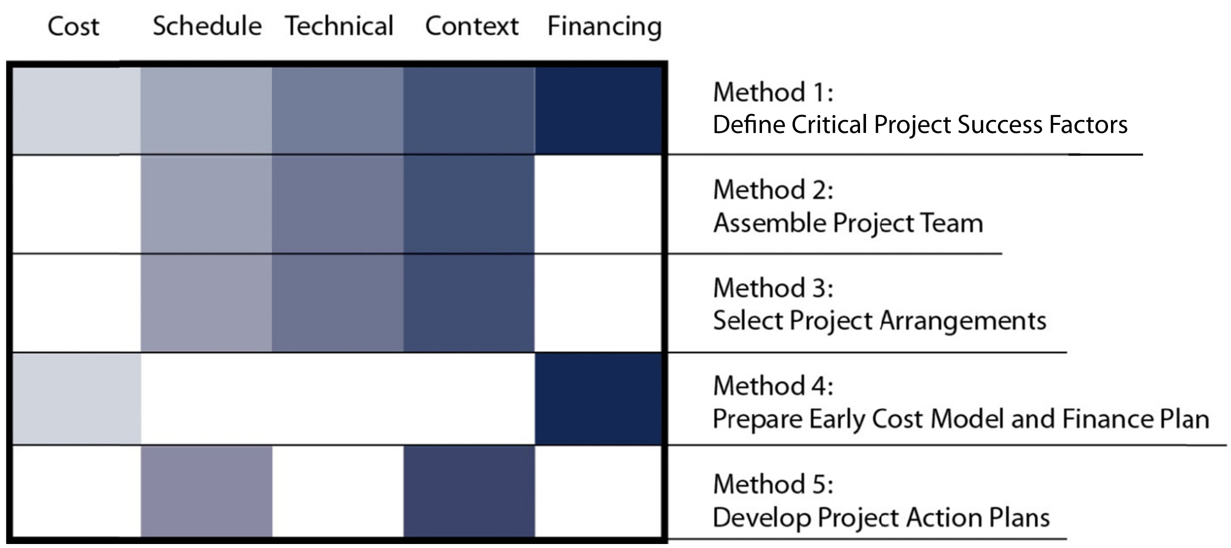


Figure 2.6. *Relationship of 5DPM complexity dimensions to project development methods.*

Figure 2.6 conceptually relates the 5DPM methods to each of the five project complexity dimensions as follows:

- Method 1, Define Critical Project Success Factors, is influenced by factors from all five dimensions.
- Method 2, Assemble Project Team, and Method 3, Select Project Arrangements, can be influenced by any of the dimensions, but they are most often influenced by factors in the schedule, technical, and context dimensions.
- Method 4, Prepare Early Cost Model and Finance Plan, is likely to be guided by factors in the cost and financing dimensions.
- Method 5, Develop Project Action Plans, responds to factors typically defined within the context dimension, but the method can be affected by the schedule's dimension.

After analyzing and mapping the nature of complexity, the project team must define critical success factors (Method 1). This step serves to communicate project goals, set team priorities, and guide resource allocation decisions (Methods 2, 3, and 4).

Project Complexity Example: I-405 in Portland, Oregon

This highway's 40-plus-year-old concrete pavement carries 125,000 vehicles per day. It has been ground down to the reinforcing steel by studded snow tires. Not only is this road in an urban area with very heavy commuter traffic but it also needs 26 bridges and overpasses to be raised to meet current FHWA clearance requirements.

Raising these structures will cause a ripple effect on the arterial and collector streets that connect with I-405 interchanges, raising their grades as well. In at least one case, the grade of the street will literally be raised to nearly the second floor of a building that fronts it. The situation is further complicated by the need to lower, relocate, or lower and relocate an unusually large number of utilities that crisscross the project limits.

In fact, the engineering is less complex than the context in which the reconstruction must take place. Highly sophisticated project management procedures will be required to complete this complex project.

FHWA (2005)

During complex-project management analysis and planning, the project team stays abreast of significant challenges that might impede project success (speed bumps) as well as absolute constraints that prevent using needed innovations to achieve success (roadblocks). The end of the analysis and planning effort is project action plans (Method 5) to overcome speed bumps and roadblocks to project success (the critical success factors evolving from complexity analysis).

If, for example, the coordination of several schedule milestones is a source of complexity, accurate scheduling is a critical success factor for the project. After defining critical success factors, the project team needs to identify the required human resources (Method 2, Assemble Project Team), develop the critical administrative resources (Method 3, Select Project Arrangements), and determine the financial resources (Method 4, Prepare Early Cost Model and Finance Plan) that are necessary to meet the critical success factors defined using Method 1.

Methods 2, 3, and 4 occur in parallel and are not independent activities. Administrative, human, and financial resources are interdependent, so these three methods must be integrated. At the completion of Methods 1 through 4, the project team should identify any remaining weaknesses or threats to project success and develop project action plans to eliminate or mitigate these threats (Method 5).

For instance, if alternative project delivery methods are not allowed by statute but the project team determines when using Method 3 that project success is dependent on the use of design–build contracts, the team should develop a project action plan to introduce enabling legislation or executive orders allowing the use of design–build for the project.

Similarly, if coordination with utilities or railroads or acquisition of ROW poses a continuing threat to project success, the team needs to develop a project action plan to address that situation.

Note that not all project action plans are targeted toward legislative or executive actions. Any stakeholder from the context dimension could be the target of a project action plan intended to improve communication, educate stakeholders, and increase the probability of project success.

3 USING THE 5DPM METHODS

3.1 INTRODUCTION

Managing modern complex renewal projects demands that the cost, schedule, technical, context, and financing dimensions are addressed in the planning process. The complex-project management team gains a firmer understanding of the nature, scope, and dynamic interaction of complexity factors by examining the factors that create complexity in each of the five dimensions.

After analyzing the sources of complexity, the team rates each dimension to facilitate the proper allocation of resources. Complexity mapping provides a useful visualization technique for quickly representing the scope, nature, and skew of project complexity. The 5DPM conceptualization process forms the basis of the five project planning and analysis methods that every complex-project manager can use (Figure 3.1).

These methods demand executive-level involvement to support project-level personnel at the very earliest stages of the project life cycle. The analysis, planning, and implementation methods also help project leaders identify which project management tools will add value to the complex-project management plan.

Planning Method 1 involves identifying critical success factors that act as a roadmap to allocate human (Method 2), administrative (Method 3), and financial (Method 4) resources to the project. The planning and resource allocation methods are represented in the guide as separate activities, but they are actually highly integrated activities that should be performed in parallel.

Any remaining barriers to success or critical resource constraints are addressed through specific project action plans (Method 5). The five methods are highly integrated and are developed through an iterative process early in the project life cycle. Once complete, the 5DPM methods are used to identify project management tools that can be used to achieve critical project success factors.

Readiness Assessments

Some 5DPM methods and tools might be new to your agency yet potentially powerful to improve your capability to manage any given complex project. At the same time, an existing method or tool that you use may be equivalent or superior to one of the 5DPM methods or tools. We include a brief question with multiple-choice answers for each of the five methods in this chapter to help you quickly assess the competency or maturity level of your organization in using each of the methods on any given project.

These quick assessments may help you to identify your risk in implementing any particular tool on a project and to determine additional resources and organizational changes to consider in addition to use of this guide, as outlined in Section 2.2 (Assessing 5DPM Readiness).

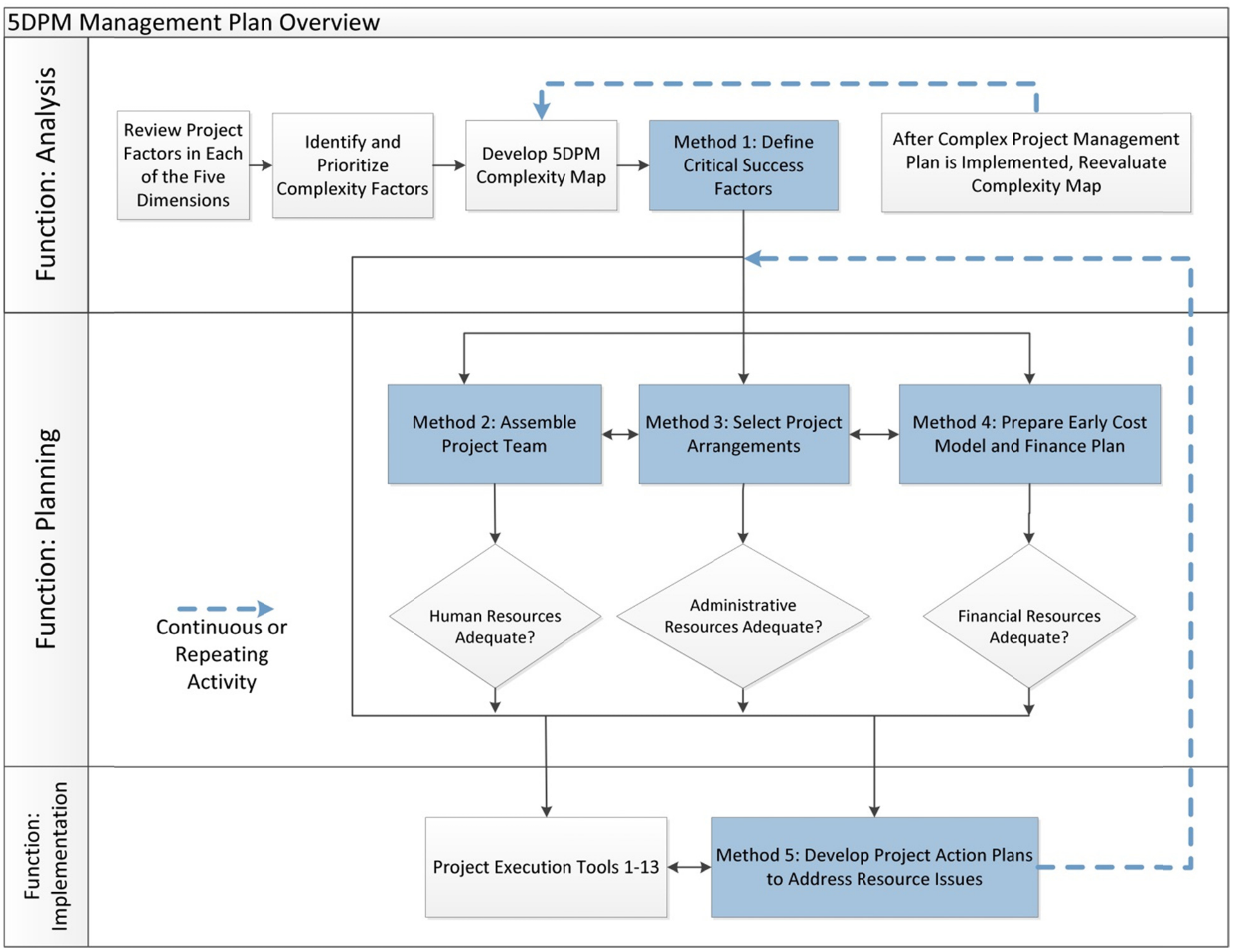


Figure 3.1. *Overview of the process for using the five project planning and analysis methods.*

3.2 METHOD 1: DEFINE CRITICAL PROJECT SUCCESS FACTORS

Overview

Use Method 1 to identify the critical success factors for all complex projects. This step is the most important aspect of managing complex projects successfully, because it literally sets the basis for making decisions throughout the project life cycle, as shown in Figure 3.2.

The dynamic interaction among project management dimensions and complexity factors can create confusion and misunderstanding among project team members. In addition, a high level of scope uncertainty generally exists for complex projects. Finally, complex projects often involve a high degree of irregularity for which industry and agency standards and project manager experience may not be available to help guide decisions. Identifying and ranking complexity factors provides useful guidance in defining critical success factors for the project.

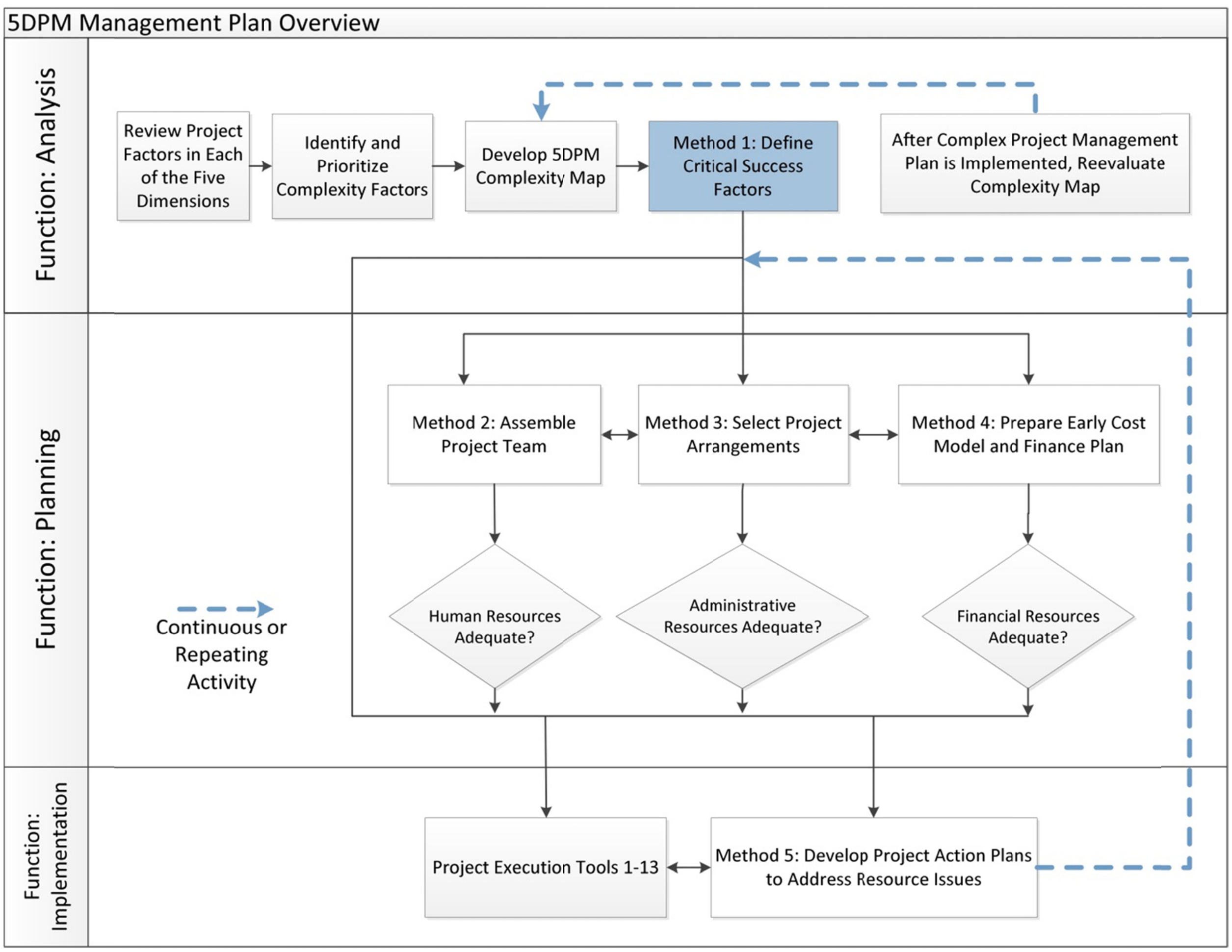


Figure 3.2. *Relationship of Method 1 to the entire 5DPM process.*

Critical project success factors typically comprise both subjective and objective inputs. The Saskatoon Green Streets project provides a good example of both. The city council decided it wanted to have the "greenest streets in Canada," which was a very subjective factor and one that enjoyed widespread public acceptance. A task force of government, academia, and industry representatives was convened to develop an action plan to achieve this lofty aspiration. Their work created an objective goal to recycle a minimum of 70% of the materials removed during demolition of existing pavements.

Method 1 Case Study Example: The Saskatoon Green Streets Project

The City Council of Saskatoon, Saskatchewan, made a decision to maximize the amount of material that was recycled in its street rehabilitation program. The city's challenging weather conditions, varying subgrade composition, and groundwater tables made adding the technical complexity of exceeding the accepted pavement design with recycled asphalt and concrete very risky.

Given that the decision had been made and public opinion was very much in favor of the council's Green Streets initiative, the solution became to develop and execute a new project delivery method called design–supply–build, in which the designer was required to assume the risk of the quality of the recycled materials by supplying them to the construction contractor.

The result was savings of $1.8 million on material costs, a compressed delivery period, and a 50% to 70% energy savings due to the reduction in transport given that more than 70% of the material was eventually recycled.

This project demonstrated the manner in which Method 1 was used to identify critical success factors in the technical, context, and schedule dimensions.

The inputs to define critical project success factors require you to identify any legislative and political directives, gather input from agency and project leaders, estimate project resource requirements and determine if they are currently available, assess community needs and influence over project feasibility, and determine project characteristics. These inputs can then be used to define critical success factors in each of the five dimensions of the 5DPM model, as shown in Figure 3.3.

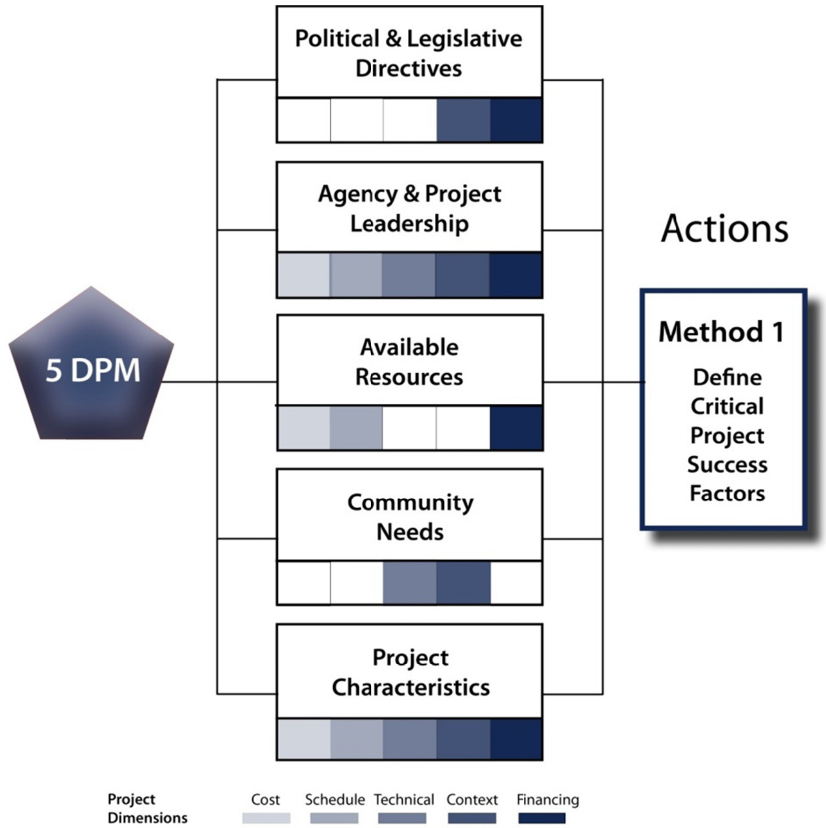


Figure 3.3. *Method 1 inputs and actions.*

The process in Saskatoon led the participants to choose Tool 1, incentivize critical project outcomes, to develop a design–supply–build delivery method by permitting the designer to make a profit by actually supplying the materials to offset the material-quality risk. The participants also chose Tool 10, establish flexible design criteria, by mandating only that the maximum amount of material be recycled instead of selecting an arbitrary percentage such as 90%. Both tools were key to the achievement of the critical success factor for sustainability.

In defining the critical project success factors, the word critical is important. The number of success factors should be relatively low, probably in the range of seven to 10 factors. If project success comes to include everything desired by everyone, the factors will not serve to guide project decisions and actions. However, it is important to realize that project success has different meanings to each stakeholder (Jacobs Engineering Group, Inc., et al. 2009) and, therefore, the definition of success should be considered from a broad perspective.

Method 1 Case Study Example: New Mississippi River Bridge Project

One of the priorities for the New Mississippi River Bridge team for the bridge between St. Louis, Missouri, and East St. Louis, Illinois, was an effort to ensure that the community continued to stay informed and involved in the project. To do that, the team established different avenues to gather input from the public, as well as different methods for the community to stay connected to the project and discover what was happening.

The community was kept aware of the special appropriations and their expiration dates, and the risks of delay were explained clearly. As a result of the open and ongoing dialogue, the project team was able to establish critical success factors for the project that enjoyed wide support among internal and external partners.

After defining the critical project success factors, the team selects project management tools (Chapter 4) to facilitate the achievement of project success. For instance, on a multimodal center, two of the tools selected might be evaluate flexible financing (Tool 11) and establish public involvement plans (Tool 13).

It is important to once again note that using Method 1 to define critical project success factors is intended to establish higher-order success factors than those typically formalized in a project mission statement or project charter, although they should all (obviously) be related. The critical success factors defined by using Method 1 should be broad enough to synthesize into a set of principles that are widely published in newsletters, websites, project signs, and so forth. A checklist like the one shown in the survey in Appendix B may be used to facilitate Method 1.

Method 1 Case Study Example: Transportation Expansion Project

The Transportation Expansion (T-REX) project in Metro Denver, Colorado, gathered inputs from several stakeholders, including elected political leaders, local and regional community groups, end users and operators, and design and construction industry leaders. As a result, the team was able to prioritize project outcomes to clearly communicate a relatively small number of critical project success factors.

The critical success factors were used to focus the project management team's attention on the use of specific tools, such as colocation and use of the earned-value or resource-loaded critical path method, which facilitated project success.

Method 1 should be started after complexity mapping and before resource allocation (Methods 2 through 4) and project action planning (Method 5) are finalized. Specific outcomes of Method 1 assist in identifying the appropriate project management tools.

The inputs to Method 1 are identified in complexity mapping and analyzing constraints and interactions. As shown with the example in Figure 3.4, common inputs are political and legislative directives, agency and project leadership opinions, available project resources, community needs, and project characteristics. These inputs are shown in the figure, and their associated complexity dimensions are highlighted.

These inputs are likely to appear on most complex projects, but other inputs may be identified in the complexity mapping process. The inputs are used to identify critical success factors, which are in turn used to achieve consensus on measurable outcomes. The team can use the critical success factors and measurable outcomes as one set of issues to consider when selecting project management tools (Chapter 4).

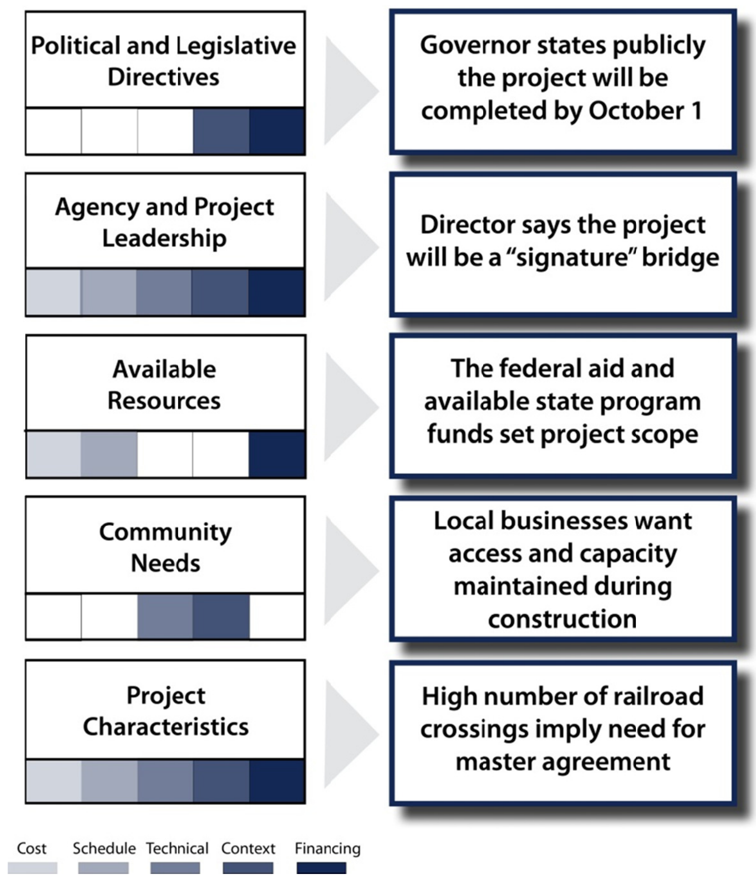


Figure 3.4. *Method 1 sample inputs and outputs for defining critical project success factors.*

Readiness to Define Critical Project Success Factors

How does your organization identify critical success factors (political and legislative issues, available resources, project characteristics, and others) of complex projects in the project planning and scoping and programming phases?

- ☐ We do not identify critical success factors in the planning or scoping and programming phases (novice).
- ☐ The project team may use its own judgment on an ad hoc basis or hire a subject matter expert (above novice).
- ☐ The project team is supposed to define critical success factors, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in defining critical project success factors that can be used in the planning or scoping and programming phases (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Where to Learn More About Defining Critical Project Success Factors

The following resources are available for more in-depth information about defining critical project success factors:

- *NCHRP Report 331: Strategic Planning and Management Guidelines for Transportation Agencies*. 1990.
- *NCHRP 20-24(63): Partnership Approaches to Identify, Promote, and Implement Congestion Management Strategies*. 2009.
- *NCHRP Web-Only Document 137: Guidance for Transportation Project Management*. 2009.
- *Twenty-First Century Leadership and Management Techniques for State DOTs,* 1st ed. AASHTO, 2009.
- *2006 CEO Leadership Forum: Advancing Practice in State DOTs from Good to Great: A Summary Report*. AASHTO, 2007.
- Partnering: A Key Tool for Improving Project Delivery in the Field. Course Number FHWA-NHI-134060.
- Leap Not Creep: Accelerating Innovation Implementation. Course Number FHWA-NHI-134073.
- Public Involvement in the Transportation Decisionmaking Process. Course Number FHWA-NHI-142036.

3.3 METHOD 2: ASSEMBLE PROJECT TEAM

Overview

The project team is the driver of the project, and selection of the appropriate people at the appropriate time is important in delivering a complex project successfully. Having the right people is important, but empowering them with the authority they need to execute their responsibilities effectively is also important.

Inputs to consider come from the complexity analysis and mapping and critical success factors identified using Method 1. Additional inputs are obtained from the resource allocation decisions made in parallel when applying Methods 3 and 4.

The inputs are used to identify the critical skill sets required for project success. Once these skill sets are ascertained, the project team can assess internal capabilities and determine any gaps in required and existing skills. You will use this gap analysis for the procurement plan described in Method 3, given that any gaps in required skill or knowledge need to be added to the team through contracts or other project arrangements, as shown in Figure 3.5.

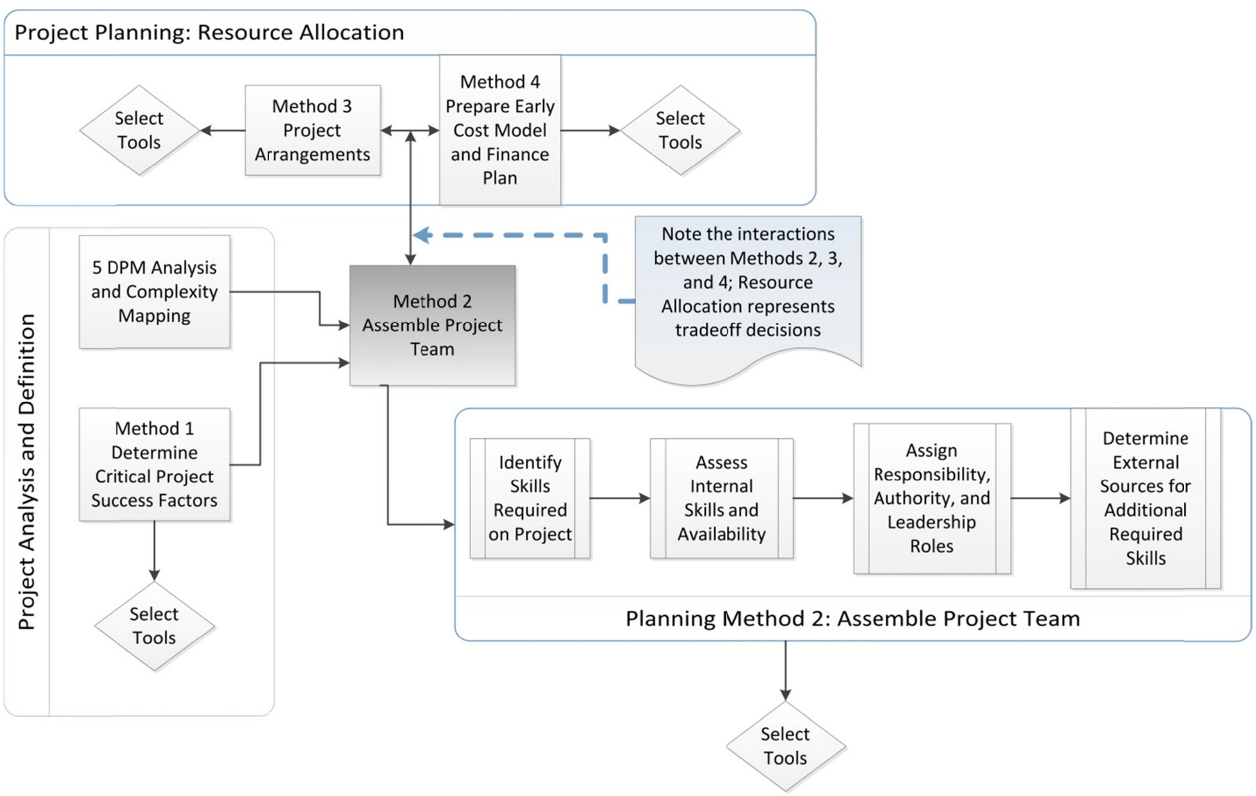


Figure 3.5. *Inputs and outputs for assembling project teams.*

Method 2 Case Study Example:
I-95 New Haven Harbor Crossing Corridor Improvement

The I-95 New Haven Harbor Crossing Corridor team in New Haven, Connecticut, was relocated to a building near the project site. This location included people in planning, design, construction, and program management organizations. This change meant creating a special Connecticut DOT district office just for this multimodal project.

Method 2 is essentially a gap analysis, in which project needs are identified in terms of skills, knowledge, responsibility, and authority and compared then to in-house resources and capabilities. The next step is to assign authority, responsibility, and leadership and determine external sources for additional required skills (e.g., other agency personnel, contractors, designers, and consultants). The project team must then clearly assign risks and responsibilities for critical project outcomes.

Finally, and perhaps most important, the project team must establish authentic authority for project decisions, including written support from top agency leaders. The outcomes of Method 2 are first to identify core in-house team responsibilities and establish authority and then identify additional team resources to add through external project arrangements.

Responsibilities for procuring external resources to fill the gaps found using Method 2 need to be clearly identified, and the team should discuss the timing for when the project will need these additional external resources. After this step, the team can select the project management tools that support project success.

Method 2 Case Study Example: Northern Gateway Toll Road

The Northern Gateway Alliance was formed by Transit New Zealand in 2004 to design, manage, and construct the Northern Gateway Toll Road. Eight organizations make up the alliance, and each member plays a critical role in ensuring an innovative, efficient, and cost-effective project.

Within the alliance, experts such as engineering consultants and specialized contractors deliver services ranging from tunneling to large-span bridge engineering and construction. Forming alliances allowed for the creation of a project team that had the complementary skills and knowledge needed to complete the project successfully.

Readiness to Assemble Project Team

How does your organization assess in-house capabilities (critical skill sets, knowledge, and resources) and responsibilities to determine the necessity for external resources that may be required in the planning, scoping and programming, preliminary engineering, and final engineering phases of project development?

- ☐ We do not consider in any particular phase (novice).
- ☐ The project team may use its own judgment on an ad hoc basis or hire a subject matter expert (above novice).
- ☐ The project team is supposed to assess in-house capabilities, responsibilities, and needs for external resources, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in assessing in-house capabilities, responsibilities, and needs for external resources (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Where to Learn More About Assembling Project Teams

The following resources are available for more in-depth information about assembling project teams:

- *NCHRP Web Document 39: Managing Change in State Departments of Transportation. Scan 7 of 8: Innovations in Public Partnering and Relationship Building in State DOTs*. 2001.
- *NCHRP 20-24(14)B: Innovations in Partnering and Relationship Building in State DOTs*. 2001.
- *NCHRP 20-24(22): Best Practices in Partnering with Public Resource Agencies*. 2003.
- *Alternative Organizational Designs for State Transportation Departments*. AASHTO, 2008.
- *AASHTO Guide for Consulting Contracting,* 1st ed. AASHTO, 2008.
- *A Transportation Executive's Guide to Organizational Improvement,* 1st ed. AASHTO, 2007.
- *Alternative Organizational Design Processes in State Departments of Transportation,* 1st ed. AASHTO, 2009.
- Partnering: A Key Tool for Improving Project Delivery in the Field. Course Number FHWA-NHI-134060.

3.4 METHOD 3: SELECT PROJECT ARRANGEMENTS

Overview

After identifying project success factors, the planning for required administrative resources (procurement and contracting for services) can be started. The most likely starting place for this planning is Method 3, Select Project Arrangements, which should be part of a deliberate project management plan based on the critical project success factors and integrated with other resource allocation methods (Method 2, Assemble Project Team, and Method 4, Prepare Early Cost Model and Finance Plan).

Method 3, one of three resource allocation methods in 5DPM, is intended to help the project team to identify administrative resources (primarily procurement processes and project delivery methods) that are best suited to the project and most likely to facilitate project success. Figure 3.6 shows the inputs and outputs for Method 3.

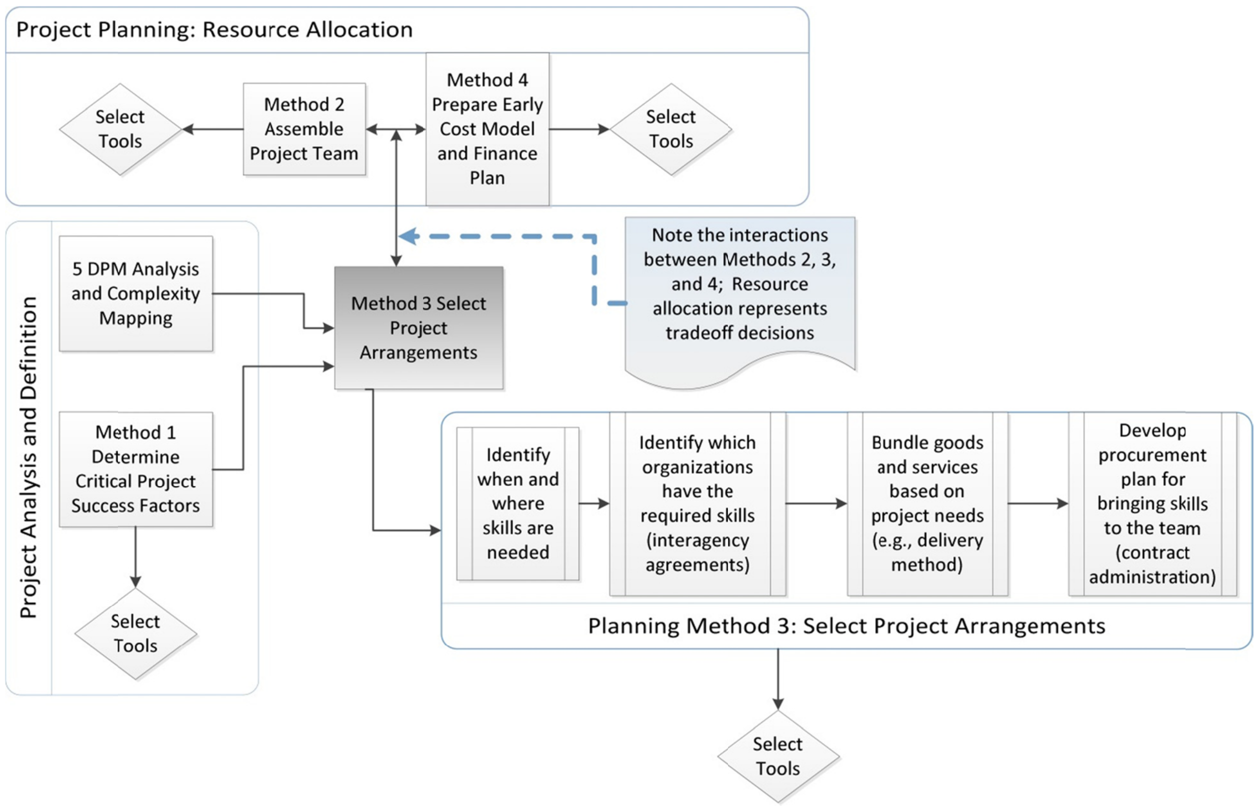


Figure 3.6. *Inputs and outputs for selecting project arrangements based on critical factors.*

Method 3 Case Study Example: I-595 Corridor

The Florida DOT sought a way to deliver the I-595 Corridor project within their budget limitation (critical success factor). This project was the first of its kind in the United States delivered with a design–build–finance–operate–maintain method. This method was particularly attractive to the Florida DOT because the financing was made available for the entire project life cycle, thus speeding up the project schedule.

Inputs to consider come from the complexity analysis and map and critical success factors identified using Method 1. Additional inputs are obtained from the resource allocation decisions made concurrently using Methods 2 and 4.

The inputs are used to develop an overall procurement plan for the services (e.g., public relations, specialty consulting, financing, design, construction) to achieve project success. The inputs are also considered in packaging services into project-specific delivery methods such as design–build (DB), construction manager–general contractor, design–supply–build, design–build–operate–transfer, and public–private partnerships (PPPs).

Method 3 Case Study Example: Lewis and Clark Bridge

The deck replacement project team for the Lewis and Clark Bridge (spanning the Columbia River between Washington and Oregon) included incentive provisions for early completion in the bid packages it prepared to control cost and schedule.

The incentive contract was new to the Washington State DOT, which added complexity to the project. The project team selected incentive contracts with early completion provisions because their major concern was local community satisfaction (critical success factor). By using the incentive contract, the project team could minimize traffic impacts to the public.

The goal of Method 3 is to identify interagency agreements, authority transfers, temporary assignments, resource sharing, contracting, bundling, and other arrangements for bringing needed skills to the team in a timely and cost-effective manner. Once the service packages that best support project success are defined, specific contracts and administrative systems can be developed.

The outcomes of Method 3 are as follows:

- Procurement plan (what we need, who we need it from, when we need it, and how much it will cost);
- Delivery methods (what goods and services we will bundle, as in DB, design–build–operate, PPP);
- Other project arrangements (interagency, utilities, railroads, authority transfers, funding) that are required to achieve project success; and
- Selection of project management tools that support project success.

Readiness to Select Project Arrangements

How does your organization identify required administrative resources (procurement process and delivery methods) to facilitate project success in the scoping and programming, preliminary engineering, and final engineering phases of project development?

- ☐ We do not consider in any particular phase (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to determine project procurement process and delivery methods, but the process is not well defined and may vary from project to project (in between with buy-in)
- ☐ We have a standard and documented process or tool in determining project procurement process and delivery methods (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Where to Learn More About Selecting Project Arrangements

The following resources are available for more in-depth information about selecting contract and delivery methods on the basis of project outcomes:

- *NCHRP Report 451: Guidelines for Warranty, Multi-Parameter, and Best Value Contracting*. 2000.
- *NCHRP Report 699: Guidelines for the Use of Pavement Warranties on Highway Construction Projects*. 2011.
- *NCHRP 10-85: A Guidebook for Construction Manager-at-Risk Contracting for Highway Projects*. 2011.
- *NCHRP Web Document 39: Managing Change in State Departments of Transportation. Scan 7 of 8: Innovations in Public–Public Partnering and Relationship Building in State DOTs*. 2001.

- *NCHRP 20-24(14)B: Innovations in Partnering and Relationship Building in State DOTs*. 2001.
- *NCHRP Web Document 30: Managing Change in State Departments of Transportation. Scan 2 of 8: Innovations in Private Involvement in Project Delivery*. 2001.
- *NCHRP 20-24(22): Best Practices in Partnering with Public Resource Agencies*. 2003.
- *NCHRP 20-24(43): Research Program Design—Administration of Highways and Transportation Agencies. Innovative Contracting for Major Transportation Projects*. 2005.
- *NCHRP 20-24(63): Partnership Approaches to Identify, Promote, and Implement Congestion Management Strategies*. 2009.
- *NCHRP Report 662: Accelerating Transportation Project and Program Delivery: Conception to Completion*. 2010.
- *NCHRP Research Results Digest 179: Financing Highway Improvements Through Public and Private Partnerships*. 1991.
- *Effective Program Delivery in a Constrained Fiscal Environment*. AASHTO, 2009.
- *AASHTO Design-Build Procurement Guide,* 1st ed. 2008.
- *AASHTO Guide for Consulting Contracting,* 1st ed. 2008.
- *AASHTO Partnering Handbook,* 1st ed. 2005.
- *Accelerating Project Delivery: It's About Time,* 1st ed. AASHTO, 2006.
- Alternative Contracting. Course Number FHWA-NHI-134058.
- FHWA Role in Public-Private Partnerships. Course Number FHWA-NHI-310116.

3.5 METHOD 4: PREPARE EARLY COST MODEL AND FINANCE PLAN

Overview

Understanding the financial model, where the funding is coming from, the sources of expenditures, and the limitations placed on design and context flexibility imposed by available funding is important to project success.

Method 4 Case Study Example: North Carolina Tollway

The North Carolina Turnpike Authority developed an early cost and finance plan that incorporated both construction costs and life-cycle costs to determine what could be delivered. This information was used to obtain bond funding for the project.

To help with the market rating on the bond market, the team was able to get legislative action whereby the North Carolina DOT agreed to pay for any cost overruns. The cost and finance plans are monitored by the North Carolina Turnpike Authority continually by requiring the design-builder to develop and maintain cost-loaded critical path method schedules. These schedules are examined by the authority, which requires that no activity cost more than $500,000.

Inputs to consider come from the complexity analysis mapping and critical success factors identified using Method 1. Additional inputs come from resource allocation decisions made concurrently using Methods 2 and 3 and are used to identify all sources of funding that are currently available, as well as the relative certainty of their availability for use on the project.

The next step is to compare the available funding to the expected cost and scope of the project. If the available resources are sufficient, the project team can incorporate the funding flows into the procurement plan and develop a relatively straightforward cost model by using standard project management tools, such as resource-loaded critical path method schedules, earned-value analysis, or cash balance–linked project draw schedules.

However, if available project funding is insufficient, then the project team must look for additional external funding sources, adjust the project scope, develop a phased approach to fit available funds, or employ a combination of those actions. The outcomes of Method 4 are a cost model for the project, a list of secure identified funding sources, positive or negative differences in fund balance, and a funding plan, as well as selection of project management tools that support project success, as shown in Figure 3.7.

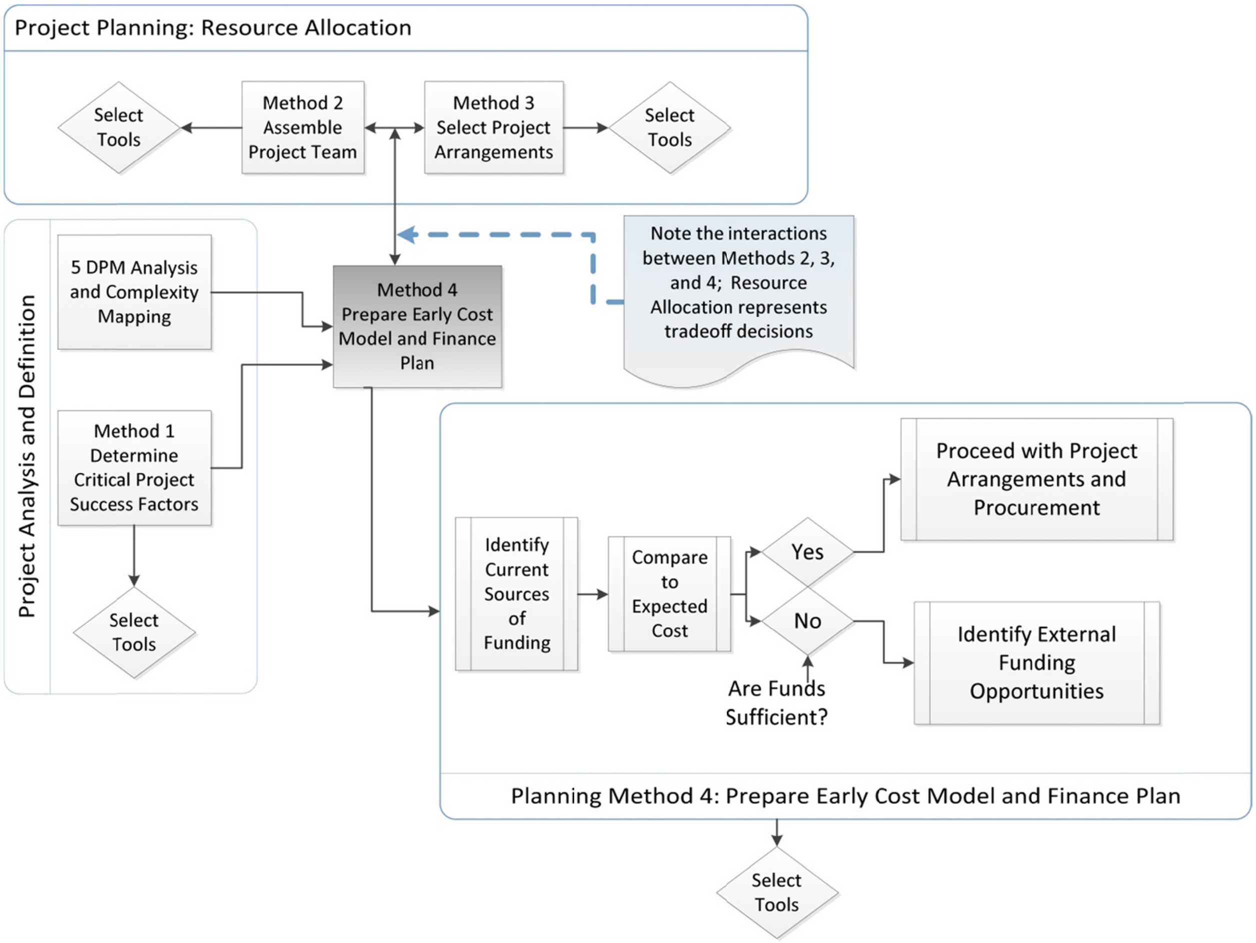


Figure 3.7. *Inputs and outputs for preparing early cost model and finance plan.*

A variety of funding sources are available, from more traditional options of taxes and fees to more innovative options of public–private finance or asset lease, as shown in Figure 3.8 by approximate year of introduction. Other less traditional options, such as artistic grants and commodity exchanges, are seen with some projects.

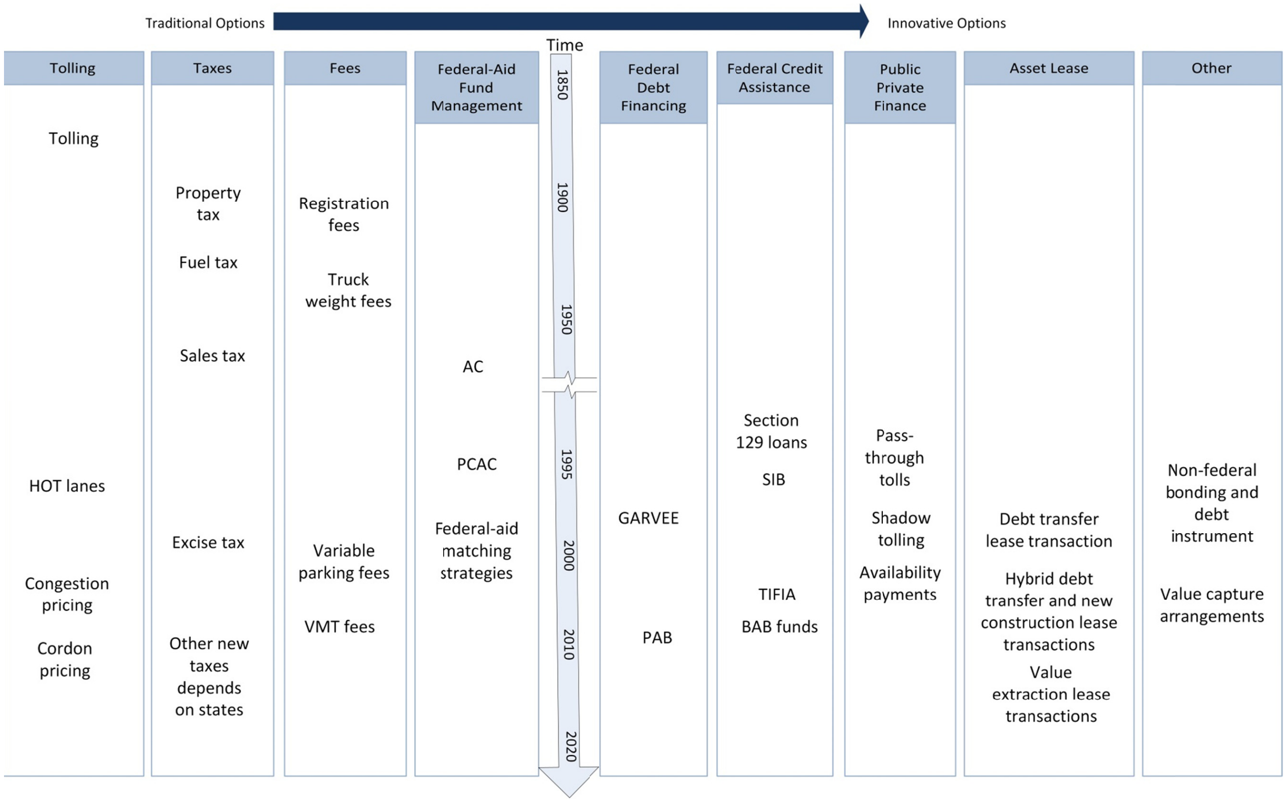


Figure 3.8. *Two potential financing options for surface transportation projects. HOT = high-occupancy toll; VMT = vehicle miles traveled; AC = advance construction; PCAC = partial conversion of advance construction; GARVEE = grant anticipation revenue vehicle; PAB = private activity bond; SIB = state infrastructure bank; TIFIA = Transportation Infrastructure Finance and Innovation Act; and BAB = Build America bond.*

Method 4 Case Study Example: Hudson-Bergen Light Rail Transit System

The Hudson-Bergen Light Rail Transit System in New Jersey 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, New Jersey Transit decided to use the design–build–operate–maintain approach for project delivery. The development of a finance plan and cost model allowed the project team to seek other sources of funds to make the project viable.

Readiness to Prepare Early Cost Model and Finance Plan

How does your organization compare the available funding and additional external funding and financing sources to the expected cost and scope of the project in the scoping and programming and preliminary engineering phases of project development?

- ☐ We do not consider in any particular phase (novice).
- ☐ The project team may use its own judgment on an ad hoc basis or hire a subject matter expert (above novice).
- ☐ The project team is supposed to prepare the early cost model and finance plan, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in preparing the early cost model and finance plan (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Where to Learn More About Preparing Early Cost Models and Finance Plans

The following resources are available for more in-depth information about preparing an early cost model and finance plan:

- *NCHRP 8-57: Improved Framework and Tools for Highway Pricing Decisions*. 2009.
- *NCHRP 20-24(13): Innovative Financing Clearinghouse*. 2002.
- *NCHRP 20-24(14)H: Innovative Finance*. 2001.
- *NCHRP 20-24(26)A: Finance Trends—Trends in Non-Federal Funding and Debt*. 2002.
- *NCHRP 20-24(26)B: Trends in Non-Federal Funding and Debt*. 2002.
- *NCHRP 20-24(51)C: State DOT Funding and Finance*. 2006.
- *NCHRP 20-24(55): National Summit on Future Transportation Funding and Finance Strategies: States and Metropolitan Regions*. 2008.
- *NCHRP 20-24(62): Communications Strategies to Increase Understanding of Funding and Revenue Needs for the Nation's Transportation System*. 2010.
- *Innovative Transportation Financing: A Report on the Results of a National Survey by the American Association of State Highway and Transportation Officials*. AASHTO, 1995.
- *Comparing State DOTs' Construction Project Cost and Schedule Performance: 28 Best Practices from Nine States*. AASHTO, 2007.

- *Report on Long-Term Financing Needs for Surface Transportation*. AASHTO, 2007.
- *Transportation—Invest in Our Future: Revenue Sources to Fund Transportation Needs*. AASHTO, 2007.
- Highway Program Financing. Course Number FHWA-NHI-152072.
- Highway Program Financing—Executive Session. Course Number FHWA-NHI-152072A.
- FHWA Role in Public-Private Partnerships. Course Number FHWA-NHI-310116.

3.6 METHOD 5: DEVELOP PROJECT ACTION PLANS

Overview

Legislators, community stakeholders, utilities, railroads, and many other individuals and groups may play an important and influential role in a complex project, more so than in traditional projects. Understanding the extent of this influence and how to direct it in a positive manner is critical to project success.

Method 5 Case Study Example: Capital Beltway

The Capital Beltway project is a complex project in northern Virginia that consists of four high-occupancy vehicle or high-occupancy toll lanes of 14 mi, lane connections, construction or reconstruction of 11 interchanges, and replacement or improvements of more than 50 bridges.

Because public expectations were high, the Virginia DOT developed a communications and outreach plan to maintain public communication 24 hours a day, seven days a week on the project and guaranteed to respond at any time of the day.

To build positive relations with the local community, the Virginia DOT sponsored and supported many civic events to help build and ensure trust. The Virginia DOT public information team was one of the largest in the state. Open, timely communication and a commitment to promises were the best response to political concerns or inquiries. Having a direct line to the secretary of transportation was effective in moving the project along and managing information for the sake of political involvement.

Project action plans either target specific stakeholders (such as attempts to change restrictive legislation to allow innovation on a specific project) or can be general in nature (such as a public information and communication plan aimed at improving project support across a wide range of stakeholders).

Inputs to consider come from the complexity analysis and mapping and critical success factors identified using Method 1. Additional inputs come from resource allocation decisions made using Methods 2, 3, and 4. Although Method 5 is labeled as the last method, as seen in Figure 2.1, developing and executing project action plans should happen throughout the project development phases. The team should start developing project action plans (Method 5) almost at project conception and continue doing so throughout project development as needed.

Inputs are used to identify what can stop the project (constraints or roadblocks) versus what can slow the project (resource limitations or speed bumps). Most speed bumps are smoothed out using Methods 2 through 4 by identifying ways to overcome resource limitations. Roadblocks are structural barriers that require innovation to overcome, which is the objective of Method 5.

Potential roadblocks and speed bumps include restrictive legislation, cooperation of utilities, right-of-way acquisition, expedited National Environmental Policy Act reviews, support of local community groups, and so forth. As a result of discussions and use of Methods 1 through 4, the project team should have a clear understanding of constraints within each of the complexity dimensions; the critical project success factors; and how to assemble the project team, select project arrangements, and prepare the early cost model and finance plan.

Again, the most complex dimension is analyzed first to determine the need for targeted project action plans, with subsequent dimensions analyzed in decreasing order of complexity. The goal of Method 5 is to develop innovative solutions to resolve (mitigate or reduce or remove or eliminate) constraints to project success, focusing on issues that cannot be resolved with existing systems, structures, practices, or resource allocations.

Method 5 Case Study Example: Louisville–Southern Indiana Ohio River Bridges

This project in Louisville, Kentucky, and southern Indiana was early in the final design stage when it was determined that the estimated project cost exceeded available funds. The project team held a series of meetings to determine if the project should be re-scoped to fit existing funding levels or if additional funds were needed (Method 4).

Once a commitment was made to holding the original scope, the project team developed an action plan to identify additional funding sources. The bistate authority was charged with recommending changes to state laws and practices that would create the flexibility needed to fund the project

Innovations using Method 5 can be administrative, contractual, technical, or methodological. The outcomes of Method 5 are a clear understanding of the influence of external stakeholders and plans for directing this influence positively to achieve project success, as well as targeted project action plans to overcome constraints (roadblocks) and limitations (speed bumps).

As with all the planning and analysis methods, one of the outcomes of Method 5 is the selection of project management tools that support project success. In addition, Method 5 may result in potential iterations of Methods 1 through 4 if their outcomes can be improved as a result of targeted project action plans. Additional outcomes of Method 5 are a list of specific targeted action plan needs and an outline of the general project action plan. Table 3.1 (and Appendix D) provides a template that you may want to use.

TABLE 3.1. DECISION PROCESS FOR DEFINING PROJECT ACTION PLANS

	Most Complex →				Least Complex
Dimension					
Success factor					
Interactions					
Adequate resources?					
Can project succeed with typical systems (Y/N)?					
If No, a roadblock or speed bump exists					
Project action plan					

Readiness to Develop Project Action Plans

How does your organization develop project action plans to address resource issues and remove or reduce potential constraints and barriers in terms of administrative, contractual, technical, or methodological perspectives in the planning, scoping and programming, preliminary engineering, final engineering, and construction phases of project development?

- ☐ We do not consider in any particular phase (novice).
- ☐ The project team may use its own judgment on an ad hoc basis or hire a subject matter expert (above novice).
- ☐ The project team is supposed to develop project action plans, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in developing project action plans (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Where to Learn More About Developing Project Action Plans

The following resources are available for more in-depth information about defining project action plans:

- *NCHRP 20-24(62): Communications Strategies to Increase Understanding of Funding and Revenue Needs for the Nation's Transportation System*. 2010.
- *NCHRP 20-24(14)B: Innovations in Partnering and Relationship Building in State DOTs*. 2001.
- *NCHRP Web Document 39: Managing Change in State Departments of Transportation. Scan 7 of 8: Innovations in Public–Public Partnering and Relationship Building in State DOTs*. 2001.
- *NCHRP 20-24(22): Best Practices in Partnering with Public Resource Agencies*. 2003.
- Federal-Aid 101 (FHWA Employee Session). Course Number FHWA-NHI-310109.
- Federal-Aid 101, Highway Program Financing and Contract Administration. Course Number FHWA-NHI-310109A.
- Federal-Aid Highways 101 (State Version). Course Number FHWA-NHI-310110.
- Introducing Highway Federal-Aid. Course Number FHWA-NHI-310115.
- Introducing Highway Federal-Aid. Course Number FHWA-NHI-310115W.
- Public Involvement in the Transportation Decision-making Process. Course Number FHWA-NHI-142036.
- Effective Communications in Public Involvement. Course Number FHWA-NHI-142059.

4 USING THE PROJECT MANAGEMENT TOOLS

4.1 INTRODUCTION

This guide provides a roadmap for managing complex projects that starts with a higher-order conceptualization of project complexity (the 5DPM model) and facilitates understanding the scope and nature of project complexity through complexity scoring and mapping.

Using the 5DPM methods, your team can select from the 13 project management tools to help achieve project success. The complex-project management process can be depicted as a funnel (Figure 4.1), with broad concepts at the top of the funnel and specific project management tools at the bottom.

Tool Selection Process

Selecting project management tools begins with defining the critical project success factors (Method 1) and continues throughout the process of using all five project development methods. Using the tool selection checklist in Appendix E, you can update and amend project management tool selection and notes throughout the development of your complex-project management plan.

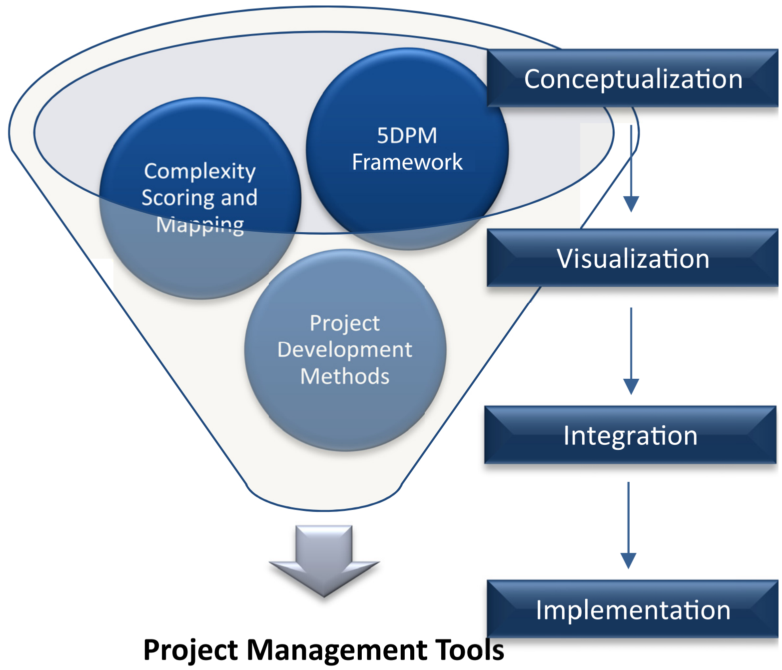


Figure 4.1. *5DPM conceptual process funnel for tool selection.*

The 13 project management tools identified through the case studies completed in the R10 research project are listed in the far-left column of Table 4.1.

Table 4.1 relates the tools to the typical project development phases by showing when your team will consider a given tool (C for consider), decide whether to use the tool (S for select), and implement the tool if it is selected (E for execute). The table provides suggestions, but depending on your project or agency characteristics, you may consider, select, and execute tools in different phases than those shown.

The list of 13 tools is not exhaustive, and project team members may identify other tools based on past experience and local requirements. As innovations in project delivery, new forms of project financing, advancements in materials and construction methods, and social, demographic, political, and legislative changes work their way into the transportation industry, new tools will become available for use on complex projects.

Figure 4.2 provides a flowchart that illustrates the tool selection process.

TABLE 4.1. TOOL SELECTION AND EXECUTION PROCESS ACROSS THE TYPICAL PROJECT DEVELOPMENT LIFE CYCLE

Tool	Typical Project Development Process Phase					
	Planning	Programming and Scoping	Preliminary Engineering	Final Engineering	Construction	Operation, Monitoring, and Maintenance
1. Incentivize critical project outcomes	C	S	E	E	E	E
2. Develop dispute resolution plans			C	S	E	E
3. Perform comprehensive risk analysis	C	S, E	E	E	E	E
4. Identify critical permit issues			C	S, E		
5. Evaluate applications of off-site fabrication			C, S, E	E		
6. Determine involvement in ROW and utilities		C	S, E	E	E	
7. Determine work packages and sequencing		C	S, E	E		
8. Design to budget		C, S	E	E		
9. Colocate team			C	S	E	
10. Establish flexible design criteria			C, S, E	E		
11. Evaluate flexible financing		C, S, E	E	E		
12. Develop finance expenditure model		C, S, E	E			
13. Establish public involvement plans		C, S, E	E			

Note: C, S, and E refer to project team actions: C = consider use; S = select; and E = execute. ROW = right-of-way.

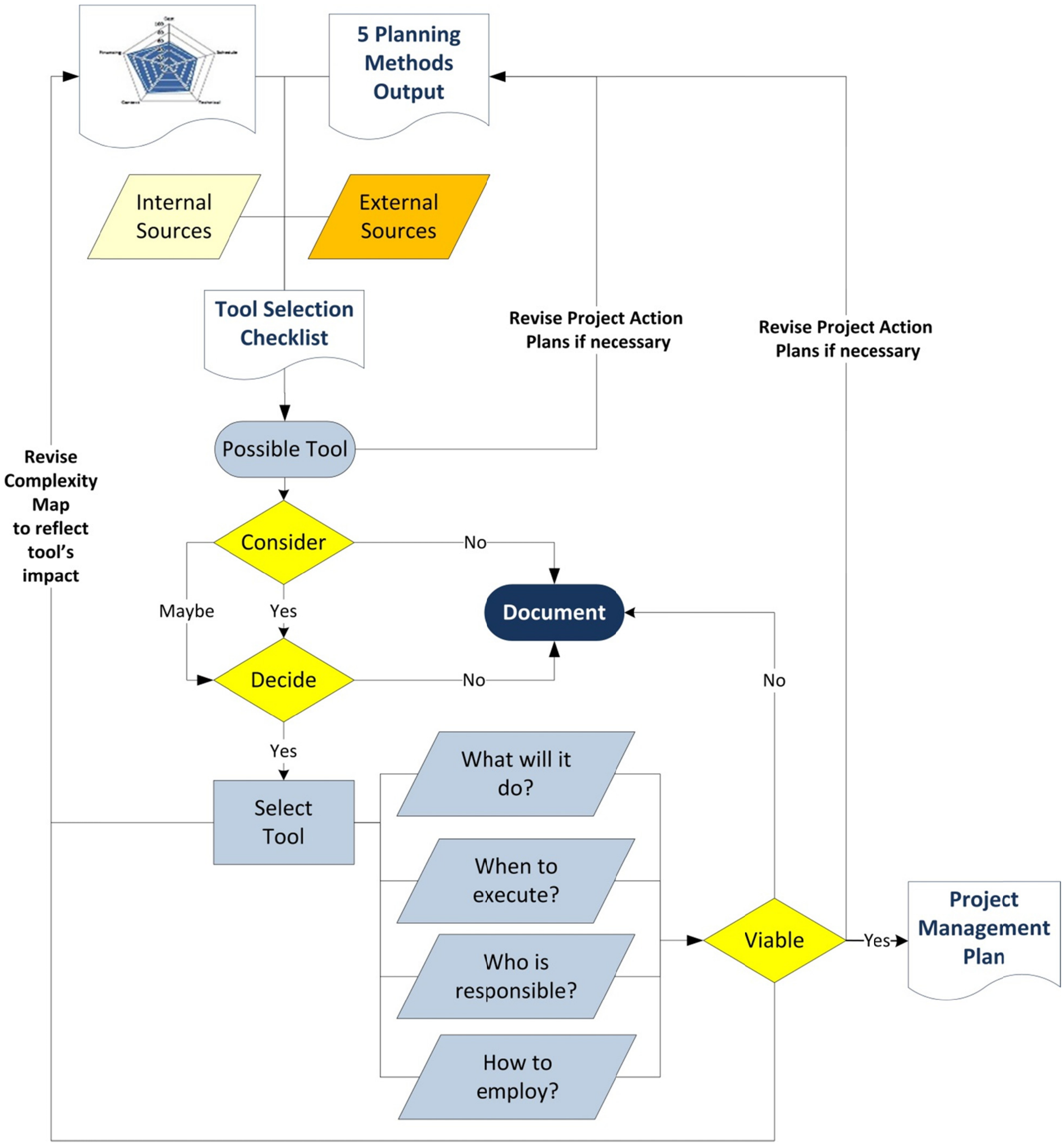


Figure 4.2. *Tool selection process.*

Figure 4.2 shows the process starting with the complexity map and the output from the five 5DPM methods, as well as information from both internal and external sources (and recall that you do not wait to begin exploring tools until all five methods are completed). An internal source might be your agency's ROW group describing constraints on project alignment, and an external source could be a community desire to have an iconic design for a bridge.

Depending on the phase of the project life cycle in which you are conducting this selection process, your team can make decisions on the use of each tool shown in Table 4.1. As shown in Figure 4.2, this process can be iterative, occurring periodically throughout your complex-project delivery period and each time you complete or revisit a method. For example, given all the necessary input and the action plans developed using Method 5, you might find it helpful to revisit the tool selection checklist in Appendix E. With that checklist, your project team can discuss the potential for using each tool in the context of your project action plans and identify the tools that may be appropriate for use on your project in an iterative manner.

Once you select and use a tool, be sure to revisit your project complexity map, update it, and reiterate the process as appropriate. Your team will also need to revise any of your project action plans that might interact as you implement use of each tool.

The tools as described represent simplified scenarios. Outcomes from implementation of individual tools may interact with outcomes or implementation of several other tools and methods. The guide descriptions attempt to capture the major interactions, but specific complex projects may have interactions not described here. Project leaders should trust their knowledge and experience: if they think there is an interaction, they should address it.

Figure 4.3 shows the tool graphic used throughout this chapter.

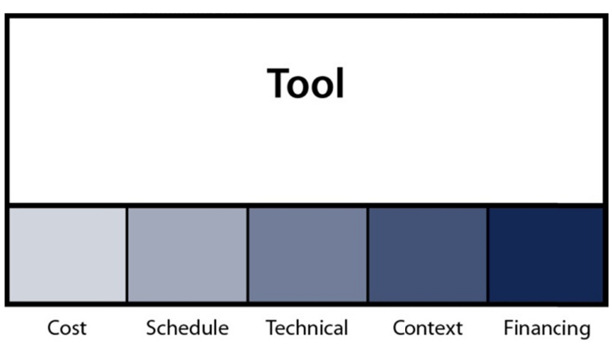


Figure 4.3. *Tool graphic.*

The intention of the graphic is to help relate the use of each of the 13 tools to managing project complexity in each of the 5DPM dimensions. The graphic contains the name of the tool at the top and boxes across the bottom for each of the five dimensions. If a box across the bottom is not shaded, the specified tool may not be appropriate for addressing complexity in that dimension.

Readiness Assessments

Some 5DPM methods and tools might be new to your agency yet potentially powerful to improve your capability to manage any given complex project. At the same time, an existing method or tool that you use may be equivalent or superior to one of the 5DPM methods or tools. We include a brief question with multiple-choice answers for each of the 13 tools in this chapter to help you quickly assess the competency or maturity level of your organization in using each of the tools on any given project.

These quick assessments may help you to identify your current use of the tools and your ability to use any particular tool on a project and to determine additional resources and organizational changes to consider in addition to use of this guide, as outlined in Section 2.2 (Assessing 5DPM Readiness).

4.2 TOOL 1: INCENTIVIZE CRITICAL PROJECT OUTCOMES

Overview

Given the previously identified outcomes, you may consider and create incentives, disincentives, or both for the project designers and contractors to meet project goals. Incentives range from traditional schedule, cost, and safety incentives to performance areas from various external factors, such as social issues, environmental issues, public involvement, and traffic mobility.

Use the outputs from the complexity identification and mapping process, as well as each of the project development methods, to identify key performance metrics to monitor for project success. Include these performance metrics specifically in individual contracts with incentive language for exceeding minimum performance.

> "The use of incentives needs to be used carefully so that the focus of the parties is bearing the shared risks."
>
> *M. Hertogh et al. (2008)*

Although traditional incentives focus on cost and schedule performance, you can write targeted contract incentives for most performance criteria, including public involvement and public relations, maintenance of traffic volumes, teamwork, design innovations, safety, and environmental performance. You can also write them for financing, construction, and/or employment contracts. Incentives and disincentives can be quite effective for complex projects.

As Figure 4.4 shows, the use of incentives can apply to complexity management for any of the five dimensions or for interactions among any of the dimensions.

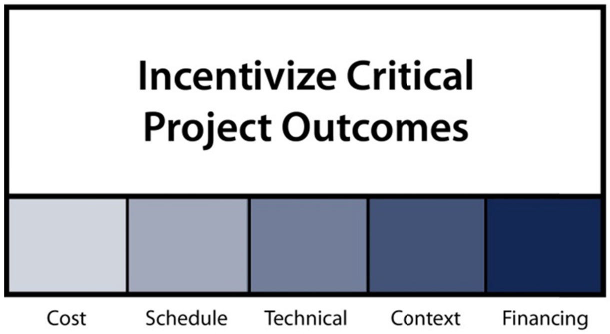


Figure 4.4. *Relationship of dimensions to Tool 1, incentivize critical project outcomes.*

When to Incentivize Critical Project Outcomes

Implement use of incentives and disincentives as early as possible in the planning process and always consider it as part of the complex-project procurement plan. Development of performance metrics and incentive language may take place multiple times on a project, particularly when partners join the team at different stages, which is frequently the case with design–bid–build.

You can make the decision to use incentives early in the planning process. However, if contract awards are made strictly on low cost (single-parameter award), the effectiveness of incentives will be diminished. The more project owners can reward value-adding activities, the more project partners are likely to align their interests with the owner organization.

Readiness to Incentivize Critical Project Outcomes

How does your organization create incentive and disincentive plans to encourage project designers, engineers, and contractors to meet critical project success factors, including schedule, cost, safety, social, environmental, public involvement, and traffic mobility?

- ☐ We do not consider in any of the project development phases (novice).
- ☐ The project team may use its own judgment on an ad hoc basis or hire a subject matter expert (above novice).
- ☐ The project team is supposed to incentivize critical project outcomes, but it is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in developing plans to incentivize critical project outcomes (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Incentivizing Critical Project Outcomes

After evaluating and mapping project complexity and developing a clear understanding of the sources of complexity on the project, perform the following steps to develop contract incentives to align the interests of contracted parties with those of the overall project, the project owner, the public at large, or a combination of them:

1. Identify critical success factors from Method 1.
2. Identify project team from Method 2.
3. Identify project arrangements from Method 3.
4. Develop performance metrics matching critical success factors. Performance metrics are used to determine if adequate or satisfactory performance is met.
5. Negotiate contracts with key team members that include performance metrics from Step 4.
6. Include incentives for exceeding minimum contract performance. Be sure to tie incentives and disincentives to performance metrics.

Examples of Incentivizing Critical Project Outcomes

Doyle Drive

For the Doyle Drive, or Presidio Parkway, project, which is a gateway to the Golden Gate Bridge in San Francisco, California, incentive clauses were included on two of eight contracts to accelerate traffic shift. Contractors submitted a cost-reduction incentive proposal that cost savings would be halved between contractors and the California Department of Transportation.

InterCounty Connector

An environmental incentive pool was set aside for each contract on the InterCounty Connector project in Montgomery and Prince George's Counties in Maryland to provide contractors with incentives to reduce environmental impacts. As a result, wetlands impacts were reduced by 40% and streams impacts were reduced by 10%. Cost incentives were issued on the basis of weekly pass–fail ratings of erosion and sediment control, and disincentives were given for failure (must pass all quarterly ratings for incentives).

New Mississippi River Bridge

On the New Mississippi River Bridge project between St. Louis, Missouri, and East St. Louis, Illinois, incentives were awarded to the railroad to complete required design work in accordance with the overall project schedule. The incentive money allowed the railroad to hire additional staff to complete required design work.

Texas State Highway 161

The schedule of construction on Texas State Highway 161 between Dallas and Fort Worth was crucial to the project. It was vitally important that the phases of the project be opened on time. Therefore, incentives, disincentives, and liquidated damages were a part of the construction contract. The contractor was able to complete the work ahead of schedule and was awarded a substantial incentive payment.

Where to Learn More About Incentivizing Critical Project Outcomes

To learn more about using critical project outcome incentives, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP Web Document 38: Quality-Based Performance Rating of Contractors for Prequalification and Bidding Purposes*. 2001.
  This study developed a comprehensive quality-based rating system for use in prequalification systems and bid evaluations. The rating system will help determine qualification for construction contract awards or bidder responsibility in states that do not conduct prequalification procedures.
- *NCHRP 10-79: Guidelines for Quality-Related Pay Adjustment Factors for Pavements*. 2011.
  This document includes the definition and purpose of quality-related pay adjustment factors. It is intended to be used by a midlevel materials or construction engineer who has an understanding of statistics and SpecRisk software.
- *NCHRP 20-24(06)A: Performance Measures for State Highway and Transportation Agencies*. 1993.
  This report evaluates the current practice in comparative program and system evaluation, the feasibility of making the comparisons, the characteristics of methodologies used to make such comparisons, and the purpose of appropriate actions.
- *Strategic Performance Measures for State Departments of Transportation: A Handbook for CEOs and Executives*. AASHTO, 2003.
  This guide describes how to develop strategic performance measures that link organizational strategic planning and performance measurements and turn them into a small group of measurable, meaningful, and accurate performance measures.
- *Incentive-Based Approaches for Environmental Stewardship*. AASHTO, 2009.
- Managing Highway Contract Claims: Analysis and Avoidance. Course Number FHWA-NHI-134037A.
  On completion of this two-and-a-half-day course, participants will be able to identify key elements of a claim, measure impacts and cost of change, and identify the dispute resolution procedures available and other various elements involved with claims and dispute resolution.
- Practical Conflict Management Skills for Environmental Issues. Course Number FHWA-NHI-142060.
  This three-day course teaches basic conflict management skills and examines opportunities for applying these collaborative skills where there are environmental issues.
- Performance-Based Contracting for Maintenance. Course Number FHWA-NHI-134079.

4.3 TOOL 2: DEVELOP DISPUTE RESOLUTION PLANS

Overview

Development of dispute resolution plans early is important for complex projects. Realizing that complex projects offer a greater number of dispute points than simple projects, thoughtful dispute resolution plans can be crucial to project success. This section provides a discussion and examples of dispute resolution plans for complex projects.

You will need to negotiate dispute resolution plans for neighborhood and community groups, U.S. DOT Section 4(f) signatories, and other indirect stakeholders on any given project. You can integrate use of this tool into development of project action plans (Method 5) and stipulate plans contractually in case scope agreement issues arise between designer and owner when selecting project arrangements (Method 3).

> "Contractually lacking a definitive chain of command for dispute resolution and implementing resolution plans has the ability to adversely affect the outcome of complex projects."
>
> *C. J. Schexnayder and R. E. Mayo (2004)*

Preparing a memorandum of agreement that all local jurisdictions are signatory to and that elaborates on the process for resolving disputes without increasing cost or schedule risk is a good practical idea.

If considering new or innovative design solutions, cooperation with designers and city and local review agencies on flexible approval processes in advance is important. Mechanistic designs and nonstandard protocols can be effective solutions in resolving conflicts or disagreements.

After identifying potential dispute areas from the complexity evaluation and use of Methods 1 through 5, the project team leaders should develop dispute resolution plans involving contracted team members, other direct stakeholders, and indirect stakeholders. The goal of a dispute resolution plan should be to identify and manage conflicts proactively before they have a negative impact on cost, schedule, or risk.

The key to any effective dispute resolution plan is to have decision makers who are empowered to bind their organizations to agreements involved in the process. Another key to effective dispute resolution is to create a project culture that respects disagreements, in that it is safe to discuss conflicts openly with the goal of quick resolution in the best interests of the project.

As Figure 4.5 shows, the development of dispute resolution plans can apply to complexity management for any of the five dimensions or for interactions among any of the dimensions.

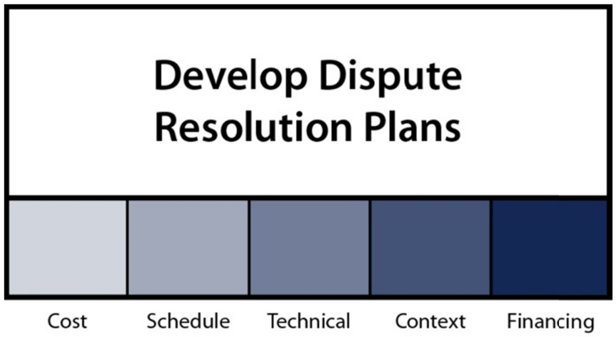


Figure 4.5. *Relationship of dimensions to Tool 2, develop dispute resolution plans.*

The use of dispute resolution plans can help in managing complexity and potential setbacks in the cost, schedule, technical (quality), context (including stakeholder issues), and financing dimensions and is highly recommended for complex projects.

When to Develop Dispute Resolution Plans

Establish your dispute resolution methods for each major project partner or stakeholder as soon as they are identified and invited (or contracted) to participate in the project. Dispute resolution methods should be agreed on before the partner's or stakeholder's formal engagement or involvement in the project if possible.

Readiness to Develop Dispute Resolution Plans

Does your organization develop dispute resolution plans involving contracted team members and direct and indirect stakeholders to identify and manage conflicts proactively?

- ☐ We do not consider in any of the project development phases (novice).
- ☐ The project team may use its own judgment on an ad hoc basis or hire a subject matter expert (above novice).
- ☐ The project team is supposed to develop dispute resolution plans, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in developing dispute resolution plans (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Developing Dispute Resolution Plans

Follow these steps in developing dispute resolution plans:

1. Identify key decision makers with each major project partner or stakeholder.
2. To the degree possible, have each partner or stakeholder organization provide written empowerment to its project representative.
3. Establish a hierarchy of dispute resolution actions and procedures and a time frame for moving disputes to the next level of the hierarchy if they remain unresolved.
4. Establish a multipartner communication protocol for sharing potential dispute issues early.
5. Clearly identify a project leader who is responsible for managing disputes and following up on resolution agreements.
6. Identify potential third-party facilitators that can be called on if needed.

Examples of Using Dispute Resolution Plans

Detroit River International Crossing

On the Detroit River International Crossing (DRIC) project, the Michigan DOT established a governance structure that was agreed on by the project partners. The Canada-U.S.-Ontario-Michigan Border Transportation Partnership consisted of FHWA, Transport Canada, the Ontario Ministry of Transportation, and the Michigan DOT.

A four-member project steering committee was established for escalation of issues (with one member from each of the entities). The goals of the project team were to resolve issues early and avoid issue escalation.

The project charter and organizational framework established a dispute resolution ladder and a communication and decision-making protocol. This framework included a procedure for project issue resolution. The project team maintained a key issue and task log database to track issues and their resolution.

InterCounty Connector

With help from an outside expert facilitator, executive or extreme partnering was promoted on the InterCounty Connector projects in Maryland. A five-tiered dispute resolution process was used. Issue-tracking methods were used to identify potential problems ahead of time. Methods included "white-listed" issues, quarterly facilitation, and a monthly form that identified potential issues.

James River Bridge/I-95 Richmond

The Virginia DOT created a downtown (Richmond) stakeholder council whose authority was to mediate specific needs for access to the Richmond central business district during construction and the need to complete the construction of the I-95 James River Bridge expeditiously.

The stakeholder council acted as a mechanism for individual business owners to present specific disputes and gain resolution without resorting to legal or extralegal means. The council decided the best course of action, and Virginia DOT then worked with its contractor to create a solution that minimized impacts on both the project and the community.

North Carolina Tollway

The North Carolina Tollway project has a dispute resolution board composed of three people. One person is selected by the North Carolina Turnpike Authority, one is selected by the design-builder, and a third is selected by the other two members of 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.

Where to Learn More About Developing Dispute Resolution Plans

To learn more about developing dispute resolution plans, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP 8-68: Citizen's Guide and Discipline-Specific Professionals' Guide for Context-Sensitive Solutions in Transportation.* 2010.
- *NCHRP 15-19: Application of Context-Sensitive Design Principles.* 2002.
- *NCHRP Legal Research Digest 50: Current Practices in the Use of Alternative Dispute Resolution.* 2008.
- *NCHRP Project 20-68A, Scan 07-01: Best Practices in Project Delivery Management.* 2009.

  The findings of this scan were that the best practices could be divided into four focus areas: (1) project management, (2) performance measures, (3) contracting practices, and (4) community involvement. The scan provides detailed information in each of the four areas.
- *NCHRP Synthesis of Highway Practice 214: Resolution of Disputes to Avoid Construction Claims.* 1995.

  This synthesis provides state-of-the-practice procedures for resolving disputes to avoid construction claims. It also emphasizes ways to settle disputes at their inception, before they become formal claims or lawsuits.
- *NCHRP Web-Only Document 184: Going the Distance Together: Citizen's Guide to Context-Sensitive Solutions for Better Transportation.* 2001.

  This web-only document covers topics such as (1) transportation and the quality of life; (2) community context, vision, values, and plans: the foundation of context-sensitive solutions; (3) shaping transportation decisions; (4) understanding professional responsibility and flexibility in project design; and (5) going the distance together: partnership through collaboration.

- *NCHRP Report 480: A Guide to Best Practices for Achieving Context-Sensitive Solutions*. 2002.

  This report covers topics such as (1) a multidisciplinary approach to context-sensitive design, (2) effective decision making, (3) reflecting community values, (4) achieving environmental sensitivity, (5) ensuring safe and feasible solutions, and (6) organizational needs.
- NCHRP Legal Research Digest 50: Current Practices in the Use of Alternative Dispute Resolution. 2008.
- This report details the current practices in various state transportation departments in the areas of environment, contracts, ROW, and torts.

4.4 TOOL 3: PERFORM COMPREHENSIVE RISK ANALYSIS

Overview

Implementation of risk analysis and mitigation plans, whether formal or informal, at early stages of the project is critical to project success. Risk analysis must include clear and concise assignment of responsibilities and designated resources. Risk analysis must also include not only traditional cost and schedule issues but also context and financing issues, such as those related to railroads, utilities, U.S. DOT Section 4(f), the National Environmental Policy Act (NEPA), appropriations, capital bill allocation (use it or lose it funding), and the effect of delays on private equity viability.

You can use risk analysis outcomes to develop aggressive mitigation plans that include the possibility of reallocating contingency within project segments or phases to prevent delays or cost increases. Early involvement from contractor groups or construction specialty review boards can be effective for input on means, methods, and material supply issues.

Use evaluation of risk probabilities (qualitative or quantitative) for potential loss events from expert panels and historical records in your prioritization and mitigation strategies. After these strategies are established, integrate your risk analysis and mitigation plan with the critical success factors for the project. Several analysis tools, software products, and spreadsheet applications are available that are a good option in helping to establish project contingencies.

As Figure 4.6 shows, performing comprehensive risk analysis can apply to complexity management for any of the five dimensions or for interactions among any of the dimensions.

Use comprehensive risk analysis to help manage direct risks from complexity in cost, schedule, scope, and quality control and indirect risks in cost, schedule, and scope arising from the potential impact of context and stakeholder issues and risks associated with project financing. Comprehensive risk analysis is highly recommended for complex projects.

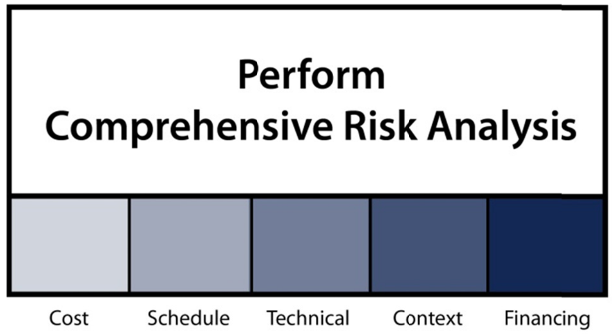


Figure 4.6. *Relationship of dimensions to Tool 3, perform comprehensive risk analysis.*

When to Perform Comprehensive Risk Analysis

Begin risk management planning in the very early stages of the project. The adequacy of risk management will be improved by following this advice:

- Start the process early.
- Include all major project team members in the process (owner, designer, financier, builder).
- Continually monitor the plan and update as needed.
- Have a two-way communication and information-sharing system that promotes consistent scanning for new and emerging risks.

> "Identifying uncertainties using project workshops is acceptable, but risk analysis should be ongoing and not be based solely on preliminary checklists and risk registers."
>
> *Edwards et al. (2009)*

Use of the comprehensive risk management tool should be considered in conjunction with incentivizing outcomes (Tool 1), dispute resolution planning (Tool 2), critical permit issue identification (Tool 4), off-site fabrication evaluation (Tool 5), determining involvement in ROW and utilities (Tool 6), designing to budget (Tool 8), establishing flexible design criteria (Tool 10), finance expenditure model development (Tool 12), and public involvement planning (Tool 13).

Readiness to Perform Comprehensive Risk Analysis

Does your organization perform a comprehensive risk analysis and develop mitigation strategies from traditional cost and schedule issues to context and financing issues?

- ☐ We do not perform a comprehensive risk analysis in any of the project development phases (novice).
- ☐ The project team may perform a risk analysis and develop mitigation strategies using its own experience and judgment or hire a subject matter expert (above novice).
- ☐ The project team may perform a risk analysis and develop mitigation strategies, but they may vary from project to project (in between with buy-in).

- ☐ We have a standard and documented process or tool in performing comprehensive risk analyses and developing mitigation strategies (some maturity or experience).
- ☐ In addition to Item 4 above, we also have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Performing Comprehensive Risk Analysis

Follow these steps in performing comprehensive risk analysis:

1. Assemble a project team with broad representation and expertise. Incorporate individuals with local knowledge, as well as those with organizational knowledge. Consider dedicated time for developing risk management plans. Consider using an outside facilitator.
2. Have the team brainstorm potential risk factors.
3. Have the team rank each potential risk factor by considering both likelihood and severity of the risk and the impact it will have on achieving project outcomes. Include discussions of both potentially negative and positive risks.
4. Develop mitigation strategies for each critical risk factor. Assign responsibility for tracking risk to a specific team member.
5. Identify project partners and other stakeholders that will have any impact on the issue or that can be influenced by the issue. The objective is to make sure the team is not trading one risk for another.
6. Allocate resources needed to support mitigation strategies. Also, consider contract language, incentives, and partnership agreements that reduce resistance to the mitigation strategy.
7. Have the project team meet frequently to update the risk management plan.
8. Integrate risk management decisions into cost estimates, project schedules, design scopes, the communication plan, and so forth.

Examples of Using Comprehensive Risk Analysis

Green Street

Risk analysis was important in the planning stage for the Green Street program for the City of Saskatoon, Saskatchewan, as well as in the design and construction phases. Overall, the risks were managed through innovation testing and mechanistic design and analysis.

I-40 Crosstown Relocation

On the I-40 Crosstown Relocation project in Oklahoma City, Oklahoma, a formal risk analysis was executed in the cost, schedule, and technical areas. The 2007 edition of the annual FHWA cost validation study found that everything was fairly close.

During this project, rapid inflation of construction material costs occurred over a period of about one year. During this period of inflation, new estimates were created every month to try to stay ahead of the rising costs.

I-95 James River Bridge

Formal risk analysis areas included cost, schedule, technical, and public opinion on the I-95 James River Bridge project in Richmond, Virginia. A risk register and public outreach were the risk identification techniques used.

New Mississippi River Bridge

On the New Mississippi River Bridge project, a formal risk analysis and mitigation process was in place that was effective in managing the cost, schedule, technical, and context dimensions.

The risk management plan was developed early in the process and was reviewed weekly, which forced the team to identify potential problems early and to develop solutions before cost or schedule was affected. Use of this tool allowed the team to get started early with railroad and utility issues that could have influenced design, increased costs, and delayed the schedule.

North Carolina Tollway

Risk analysis was part of the bonding process on the North Carolina Tollway. The project needed an AA rating on the bond market to get a better interest rate and to be a low-risk project. The North Carolina Turnpike Authority bought bond insurance against the toll revenue, which originally had a medium to moderate risk.

The toll revenue was not shown to cover the total cost of the project, so legislation provided gap funding that gave the project the low-risk AA rating. If the gap funding had not been provided, the project would not have gone through.

Where to Learn More About Performing Comprehensive Risk Analysis

To learn more about performing comprehensive risk analysis, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *SHRP 2 R09: Guide for the Process of Managing Risk on Rapid Renewal Projects*. 2011.
  This guide outlines a formal risk management process that helps optimize performance for accelerated reconstruction projects. It also includes practical methods for identifying, assessing, mitigating, allocating, and monitoring risk.
- *SHRP 2 R16: Strategies for Improving the Project Agreement Process Between Highway Agencies and Railroads*. 2010.
  This project includes model legal agreements, recommended practices, sample contracts, and training material to resolve underlying sources of conflicts and streamline review and agreement processes.

- *NCHRP 20-24(74): Executive Strategies for Risk Management Practices by State Departments of Transportation*. 2011.
  This is a currently active project. The objective is to develop a guide for the use of risk management to support (1) early identification of key issues that may significantly slow or block successful project delivery, (2) effective application of management action and other resources to avoid or mitigate the delays these issues represent, and (3) better decision making in project planning and programming.
- *NCHRP 20-59(17): Guide to Risk Management of Multimodal Transportation Infrastructure*. 2008.
  The objective was to create a guide that provided agencies with a risk management methodology that can be used to conduct threat, vulnerability, and criticality assessments of facilities. This guide also found cost-effective countermeasures to prevent, detect, and reduce threats to assets on a multimodal basis.
- *NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs*. 2010.
  This report contains topics such as (1) project cost estimation and management, (2) an overview of risk management, (3) guide to the planning phase, (4) guide to the programming phase, (5) guide to the design phase, and (6) implementation.
- *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*. 2007.
  This report contains topics such as (1) agency cost estimation practice and cost estimation management processes, (2) factors and strategies, (3) guide for planning phase, (4) guide for programming and preliminary design phase, (5) guide for final design phase, and (6) implementation.
- *NCHRP Synthesis of Highway Practice 402: Construction Manager-at-Risk Project Delivery for Highway Programs*. 2010.
  This synthesis offers an overview of the various techniques used by transportation agencies when implementing the construction manager-at-risk project delivery method.
- *Guide to Risk Assessment and Allocation for Highway Construction Management*. FHWA, 2006.
- Risk Management. Course Number FHWA-NHI-134065.
  This two-day course provides participants with an understanding of risk management concepts and processes.
- Risk Management Executive Summary. Course Number FHWA-NHI-134065A.

4.5 TOOL 4: IDENTIFY CRITICAL PERMIT ISSUES

Overview

Development of timelines for environmental, U.S. DOT Section 4(f), and other critical regulatory reviews very early in the project life cycle is critical for successful projects. For complex-project success, develop flexible response mechanisms for permit issues and look at flexible planning and design for minimal impact from permit issues, particularly when uncertainty is high (e.g., geotechnical and subsurface conditions, State Historic Preservation Office sites).

> "Environmental limitations need to be compared with other factors such as cost, safety, and technical decisions to determine the best solution and the ideal trade-off scenario."
>
> *Trapani and Beal (1983)*

As Figure 4.7 shows, identifying critical permit issues can apply to complexity management for any of the five dimensions or for interactions among any of the dimensions.

Critical permit issues can control the cost, schedule, and scope impacts arising from context and stakeholder issues, and availability of financing may be dependent on minimizing schedule and cost growth related to permit issues. Identification of critical permit issues is highly recommended for complex projects.

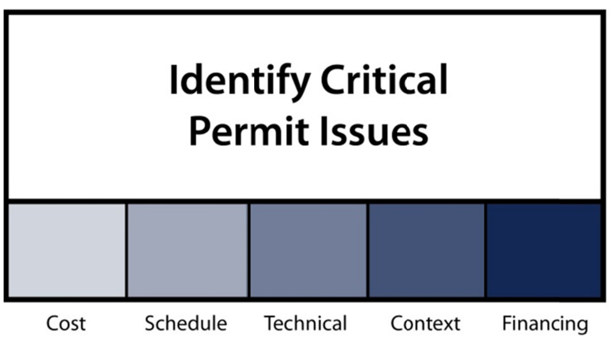


Figure 4.7. *Relationship of dimensions to Tool 4, identify critical permit issues.*

When to Identify Critical Permit Issues

To be effective, this tool should be implemented in the very early stages of planning, preferably before alignments have been finalized and irreversible design decisions have been made. You need to evaluate critical permit issues as soon as possible. If permits cannot be obtained immediately, make sure the design is flexible enough to be changed if necessary.

Readiness to Identify Critical Permit Issues

How does your organization identify critical permit issues to minimize their negative impacts on cost, schedule, technical scope, context, or financing in the scoping and programming and preliminary engineering phases of project development?

- ☐ We do not consider in the scoping and programming or preliminary engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to identify critical permit issues, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in identifying critical permit issues (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Identifying Critical Permit Issues

Information from the complexity evaluation and mapping process and the definition of critical success factors (Method 1) provide insight into critical permit issues that may have a potential negative impact on cost, schedule, technical scope, context, or financing. In addition, permit issues may be identified in comprehensive risk analysis (Tool 3).

Follow the steps for use of this tool to minimize critical permit issue impacts on the schedule and to assign design and planning activities as needed to fast-track aspects of the work. Early identification of critical permit issues can also act as "due diligence" in establishing working relationships with permitting agencies. It can be very beneficial to have a dialogue on how separate agencies can work together to minimize the negative impact the permitting process might have on the project, while at the same time allowing the permitting agency to share its primary concerns with the project team. The steps in this process are as follows:

1. From the complexity mapping process and the outcomes of Methods 1 through 5, identify the critical permit issues that must be resolved before design can be completed and construction can begin.
2. Discuss potential major regulatory issues with responsible agencies and use flexible designs to minimize the impact of potential points of conflict with permitting agencies (i.e., be responsive to their concerns).
3. Make early contact with regulatory agencies responsible for permits to communicate and coordinate submittal and approval schedules. Investigate the potential for phased permitting, simultaneous reviews, fast-tracking, and so forth.
4. Ensure that submittal packages are coordinated, complete, and timely.

Examples of Critical Permit Issue Identification

Detroit River International Crossing

The DRIC project was monitored at the U.S. DOT level because it was included on then-President Bush's list of the top 10 projects requiring streamlining. This streamlining required senior leadership support from various federal agencies and the commitment to reduce or eliminate barriers and to work cooperatively.

The team created a "green sheet" from the Record of Decision that identified the required mitigation measures. The sheet provided a simple summary of the mitigation requirements to assist with monitoring and accountability.

I-95 New Haven Harbor Crossing Corridor Improvement

On the I-95 New Haven Harbor Crossing Corridor (NHHCC) project, the Connecticut DOT held biweekly program manager meetings to ensure that permits and ROW were acquired on time.

Lewis and Clark Bridge

The project team for the Lewis and Clark Bridge, which spans the state line between Washington and Oregon, developed a protocol plan to manage critical permit issues. The plan clarified timing of action, responsible personnel to act, the back-up plan, and things to do first.

Louisville–Southern Indiana Ohio River Bridges

On the Louisville–Southern Indiana Ohio River Bridges project, which addresses long-term, cross-river transportation needs in southern Indiana and Louisville, Kentucky, thorough preparation and background documentation for the environmental impact statement and U.S. DOT Section 4(f) processes were critical, and managing them simultaneously was useful in keeping the project moving forward.

Where to Learn More About Identifying Critical Permit Issues

To learn more about identifying critical permit issues, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP 8-68: Citizen's Guide and Discipline-Specific Professionals' Guide for Context-Sensitive Solutions in Transportation.* 2010.
  This report covers topics such as (1) transportation and the quality of life; (2) community context, vision, values, and plans: the foundation of context-sensitive solutions; (3) shaping transportation decisions; (4) understanding professional responsibility and flexibility in project design; and (5) going the distance together: partnership through collaboration.
- *NCHRP 20-24(71): Expediting NEPA Decisions and Other Practitioner Strategies for Addressing High-Risk Issues in Project Delivery.* 2010.
  This is a currently active project. The objective is to develop a guide for the use of risk management to support (1) early identification of key issues that may significantly slow or block successful project delivery, (2) effective application of

management action and other resources to avoid or mitigate the delays these issues represent, and (3) better decision making in project planning and programming.

- *NCHRP Report 351: Hazardous Wastes in Highway Rights-of-Way.* 1993.
- *NCHRP Report 379: Guidelines for the Development of Wetland Replacement Areas*. 1996.
  This project outlines a well-defined wetland replacement process. It also includes guidelines for the creation of wetland banks that could be used for trade at a later date when no other option is applicable.
- *NCHRP Report 474: Assessment of Impacts of Bridge Deck Runoff Contaminants on Receiving Waters,* Vols. 1 and 2. 2001.
  This project included a review of literature, a survey of highway agencies, development and testing of biological studies, and the design of a process to evaluate the impact of bridges on water quality.
- *NCHRP Report 565: Evaluation of Best Management Practices for Highway Runoff Control*. 2006.
  This report provides background information on typical storm water best management practices and application of low-impact development in the highway environment, the treatment processes for storm water, the influences of highway and hydrologic characteristics, and institutional and regional influences. It also discusses performance evaluation, and an overall evaluation strategy is outlined.
- *NCHRP Technologies to Improve Consideration of Environmental Concerns in Transportation Decisions* (CD-ROM). 2001.
  This phase of the project identified and critiqued 26 technology applications used to improve the consideration of environmental concerns in transportation projects. It uses a fictional case study to demonstrate these applications.
- *NCHRP Research Results Digest 304: Technologies to Improve Consideration of Environmental Concerns in Transportation Decisions*. 2006.
  This phase of the project, which is a continuation of the NCHRP 25-22 project, uses the findings of the first phase and identifies, profiles, and demonstrates eight of the existing technology applications through coordination with state DOTs.
- All of AASHTO Practitioner's Handbooks.
  A variety of handbooks covering topics such as maintaining a project file and preparing an administrative record for a NEPA study, responding to comments on an environmental impact statement, complying with Section 4(f) of the U.S. DOT Act of 1966, developing and implementing a storm water management program in a transportation agency, and many more.
- NEPA and Transportation Decisionmaking. Course Number FHWA-NHI-142005.
  This three-day course teaches participants about NEPA principles and the umbrella concept in transportation decision making. It also explains each participant's roles and responsibilities and the importance of a collaborative process when evaluating alternatives. It lists the milestones and describes documentation requirements and how to manage the NEPA process.

- Beyond Compliance: Historic Preservation in Transportation Project Development. Course Number FHWA-NHI-142049.
  This three-day course will help participants to identify historic preservation laws; describe the Section 106 process, the roles and responsibilities of all parties involved in the process, and how it relates to NEPA project development and Section 4(f); describe the NEPA decision-making process; and identify opportunities for environmental streamlining and stewardship.
- Introduction to NEPA and Transportation Decisionmaking. Course Number FHWA-NHI-142052.
  This four-hour course offers an introduction to NEPA that includes the origin and intent of NEPA; the umbrella concept; NEPA principles, roles, and responsibilities; and the documentation requirement of the NEPA process.
- Practical Conflict Management Skills for Environmental Issues. Course Number FHWA-NHI-142060.
  This three-day course will teach basic conflict management skills and will examine opportunities for applying these collaborative skills when there are environmental issues.

4.6 TOOL 5: EVALUATE APPLICATIONS OF OFF-SITE FABRICATION

Overview

Consider off-site fabrication not only for cost or schedule control purposes, but also for quality (technical) control, minimal public disruption (such as noise and loss of access), and environmental impact control. Considering that complexity on projects may come from context issues, off-site fabrication can be a good solution for external issues in minimizing road closures, disruption to local business, traffic delays, detour lengths, and public inconvenience.

As Figure 4.8 shows, the need to evaluate off-site fabrication applications arises primarily from complexity in the cost, schedule, technical, and context dimensions or from the interactions among them.

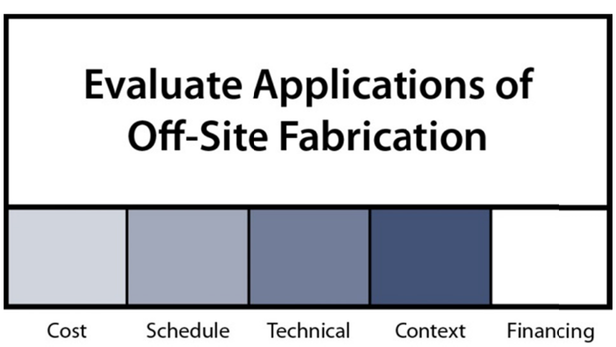


Figure 4.8. *Relationship of dimensions to Tool 5, evaluate applications of off-site fabrication.*

> "Prefabricated bridge elements and systems offer bridge designers and contractors significant advantages in terms of construction time, safety, environmental impact, constructability, and cost."
>
> *Fowler (2006)*

Schedule complexity may be created by context issues, such as high-volume traffic and lack of suitable detours, but the use of off-site fabrication will be determined by an analysis of the trade-offs in cost, schedule, and design quality and serviceability. Therefore, at least within the context of the 5DPM framework in this guide, off-site fabrication can help manage cost, schedule, and technical complexity, which in turn may be a solution for context and stakeholder constraints.

Evaluation of off-site fabrication applications is recommended for complex projects that need cost, schedule, and serviceability optimized to facilitate project success.

When to Evaluate Off-Site Fabrication Applications

Evaluate off-site fabrication options in the planning stages before design is finalized. A final commitment to off-site fabrication must be rendered early in the design phase.

Readiness to Evaluate Off-Site Fabrication Applications

How does your organization consider the possibility of off-site fabrication applications to control schedule and quality or minimize public disruption (such as noise and road closures) in the scoping and programming and preliminary engineering phases of project development?

- ☐ We do not consider in the scoping and programming or preliminary engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to evaluate application of off-site fabrication, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in evaluating application of off-site fabrication (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Evaluating Off-Site Fabrication Applications

Follow these steps to evaluate off-site fabrication applications:

1. Identify road-user costs, feasibility of detours, alternate routes for emergency response vehicles, and other factors to determine if construction must proceed under traffic.

2. If construction must proceed under traffic, determine the impact of the project on capacity and mobility through the work zone.
3. Analyze design options that incorporate off-site fabrication of project elements (e.g., substructure, superstructure, deck).
4. Compare the total cost (including road-user costs), quality, and schedule benefits to any potential increases in construction costs, decrease in functionality, or both.
5. Identify capabilities of local sourcing options and contracting requirements for securing sufficient, timely supply.

Examples of Evaluating Off-Site Fabrication Applications

I-40 Crosstown Relocation

The I-40 Crosstown Relocation project manager in Oklahoma City, Oklahoma, credits an FHWA Accelerated Construction Technology Transfer workshop with identifying the idea to base all bridge designs on a standard set of precast structural members.

I-95 James River Bridge

The system of prefabricated bridge elements was seen as very efficient for the I-95 James River Bridge project in Richmond, Virginia. The benefits of using prefabricated bridge elements are 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" (Andrle et al. 2003).

Lewis and Clark Bridge

The construction strategy on the Lewis and Clark Bridge (spanning the state line between Washington and Oregon) reduced the time during which construction affected traffic. The contractor revised the placement procedure by using self-propelled modular transporters with a specially designed steel truss frame for lifting and transporting, which enabled contractors to meet the scheduling constraints. The transporters 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. By using the self-propelled modular transporters, construction time on the bridge was reduced, minimizing the impact on traffic for the public, even though the overall schedule for the bridge work remained unchanged.

Where to Learn More About Evaluating Off-Site Fabrication Applications

To learn more about evaluating off-site fabrication applications, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *SHRP 2 R04: A Toolkit for Accelerated Bridge Construction*. 2013.
- *NCHRP Synthesis 393: Adjacent Precast Concrete Box Beam Bridges*. 2011.
- *NCHRP Report 407: Rapid Replacement of Bridge Decks*. 1998.
  This report identifies the need for optimized systems for rapid replacement of bridge decks to minimize delays during rehabilitation of bridge decks. It also has recommendations for details of new superstructures to facilitate future rapid replacement.
- *NCHRP Report 584: Full-Depth Precast-Concrete Bridge Deck Panel Systems*. 2008.
  This report identifies guidelines for precast-concrete bridge deck panel systems and durable, rapid construction connections between panels. The use of this system reduces total deck construction time.
- *NCHRP Web-Only Document 173: Cast-in-Place Concrete Connections for Precast Deck Systems*. 2011.
- *NCHRP Report 681: Development of a Precast Bent Cap System for Seismic Regions*. 2011.
- *NCHRP 18-12: Self-Consolidating Concrete for Precast, Prestressed Concrete Bridge Elements*. 2004.
- *SHRP 2 R05 Report S2-R05-RR-1: Precast Concrete Pavement Technology*. 2013.
- *Accelerated Bridge Construction: Experience in Design, Fabrication, and Erection of Prefabricated Bridge Elements and Systems*. FHWA, 2011.
- *Connection Details for Prefabricated Bridge Elements and Systems*. FHWA, 2009.
- *User and Non-User Benefit Analysis for Highways,* 3rd ed. AASHTO, 2010.
  This report analyzes the benefits and costs of highway projects. The material supports transportation planners who evaluate highway investments.
- *Accelerating Project Delivery: It's About Time,* 1st ed. AASHTO, 2006.
  This report highlights current construction acceleration techniques that agencies are using.

4.7 TOOL 6: DETERMINE INVOLVEMENT IN ROW AND UTILITIES

Overview

Determination of the required involvement in ROW and utilities should be based on the critical project success factors. Even when contractual responsibilities for coordinating ROW and utilities are assigned to the contractor or design-builder, it is the owner agency and general public that ultimately suffer if ROW and utility (including railroads) issues are not integrated into the overall project.

As Figure 4.9 shows, determining the required involvement in ROW and utilities arises primarily from complexity in the cost, technical, and context dimensions or from the interactions among them.

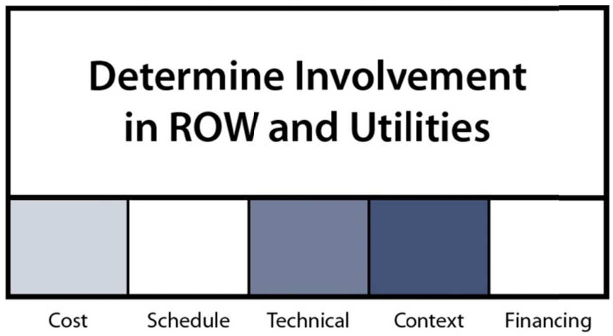


Figure 4.9. *Relationship of dimensions to Tool 6, determine involvement in ROW and utilities.*

Paying additional design staff to assist railroads and utilities with design reviews or planning can be an option for project success. To the extent possible, it is important to incorporate ROW, railroad, and utilities as project partners (rather than as adversaries) and to develop win–win solutions to issues involving potential delay or cost increases.

In the context of the 5DPM model, complexity arises from the presence of a necessary interaction with a ROW holder (such as a railroad) or a utility that cannot be avoided because of excessive cost or lack of alternate technical solutions (e.g., no substitute alignment or configurations).

The interaction of these constraints will result in schedule delays if not managed properly. In other words, the involvement of utilities and ROW holders may offer some flexibility in staffing, incentives, early coordination, and so forth that can minimize potential schedule impacts. Therefore, at least within the context of the 5DPM framework, involvement of utilities and ROW holders can help manage schedule impacts created by cost and technical constraints.

> "Systematic and structured processes for right-of-way estimating and cost management are lacking in many state highway agencies. The lack of defined processes impacts the agency's ability to consistently produce accurate right-of-way cost estimates."
>
> *Anderson et al. (2009)*

Determining the required involvement in ROW and utilities is required for complex projects when cost and technical constraints make close coordination in these respects a must for project success.

When to Determine Involvement in ROW and Utilities

To be effective, this integration tool should be implemented in the very early stages of design so the partners have time to provide timely information to designers before letting construction contracts. If design–build (DB) delivery is to be used, address the ROW, utility, and railroad integration issues in the request for qualifications or request for proposal development stage at the latest, before award of the DB contract.

Readiness to Determine Involvement in ROW and Utilities

How does your organization determine the level of involvement in ROW, railroad, and utilities issues (e.g., relocation) to prevent potential delay or cost increases in the planning, scoping and programming, preliminary engineering, and final engineering phases of project development?

- ☐ We do not consider in the planning, scoping and programming, preliminary engineering, or final engineering phases of project development because it is the assigned contractors' responsibility (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to determine the level of involvement in issues, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool for determining the level of involvement (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Determining Involvement in ROW and Utilities

Follow these steps in determining the required involvement in ROW and utilities:

1. From the complexity analysis, results from using Methods 1 through 5, and comprehensive risk analysis (Tool 3), identify potential negative project impacts from poorly integrated ROW, utility, or railroad conflicts.
2. Discuss major information and integration needs with ROW, utilities, and railroads. Hold early discussions with individuals who are empowered to commit the organizations to action.
3. Recognize potential organizational and goal conflicts and discuss mutually beneficial options openly (i.e., look at issues from the other party's viewpoint).
4. Allocate project resources (e.g., staff, money, support software) to the ROW, utility, or railroad as needed to facilitate integration into overall project objectives and success.

5. Assign a team member the specific responsibility to track communication and integration progress with each ROW, utility, or railroad partner.

Examples of Determining Involvement in ROW and Utilities

InterCounty Connector

A tracking log was used for ROW coordination on the InterCounty Connector projects in Maryland. Utility agreements that were used for utility coordination were a big contributor to project success. The task force team had weekly meetings for utility coordination.

I-95 James River Bridge

The Virginia DOT did a comprehensive analysis of ROW requirements at the outset of project development on the I-95 James River Bridge. They identified temporary easements during construction and utility issues that required immediate action to facilitate project progress.

North Carolina Tollway

To help with the effort to acquire ROW on the North Carolina Tollway project, the design-builder created a priority list for the North Carolina Turnpike Authority to work with.

T-REX

Because the Transportation Expansion (T-REX) project in Metro Denver, Colorado, was an expansion of an old urban corridor, existing utilities were one of the biggest risks on the project. The Colorado DOT and Regional Transportation District 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 contactors completed $2.5 million of utility relocation work before the project contractor received notice to proceed. Identifying existing utilities and relocating them early provided less risk to the contractor.

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. The experts explained homeowner and tenant rights and provided help with financing and locating replacement housing. Relocation benefits included home-buying assistance and money to supplement rent and moving costs (B-85 assistance). The T-REX project required 30 total acquisitions and 172 partial acquisitions.

Where to Learn More About Determining Involvement in ROW and Utilities

To learn more about determining the required involvement in ROW and utilities, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP 20-24(22): Best Practices in Partnering with Public Resource Agencies*. 2003.
- *NCHRP 20-24(54)B: Right-of Way and Environmental Mitigation Costs—Investment Needs Assessment*. 2006.

  The purpose of the study was to develop estimates of planning and environmental costs. This goal was met through a survey of five agencies and 29 projects. Because of the wide range of ROW and mitigation costs, the findings can be applied relative to an overall program or used for a hypothetical average project.
- *NCHRP Report 351: Hazardous Wastes in Highway Rights-of-Way.* 1993.
- *NCHRP 20-84: Improved Right-of-Way Procedures and Business Practices*. 2012.

  The objectives of this currently active project are to develop improved ROW procedures and business practices, and best practices for the long-term management of ROW assets.
- *NCHRP Synthesis of Highway Practice 413: Techniques for Effective Highway Construction Projects in Congested Urban Areas*. 2011.

  This study focused on the techniques used by agencies to effectively deal with high traffic volumes, significant utility conflicts and relocations, complex ROW acquisition actions, a diverse stakeholder base, and attentive media markets. The study identified the strategies, determined how agencies rated their success, and examined the applicability of the strategies to other projects.
- *Guidance on Sharing Freeway and Highway Rights-of-Way for Telecommunications, 1st ed.* AASHTO, 1997.

  This guidebook includes topics related to designating a project champion, assembling an information base, finding the right partners, negotiating partner responsibilities, monitoring existing partnerships, and considering future partnerships.
- *A Policy on the Accommodation of Utilities Within Freeway Right-of-Way,* 5th ed. AASHTO, 2005.

  This guidebook covers topics including new and existing utilities along freeways, major valley or river crossings, utilities crossing freeways, utilities in vehicular tunnels, access for constructing and servicing utilities, construction and location details, and manner of making utilities installations and adjustments.
- *A Guide for Accommodating Utilities Within Highway Right-of-Way,* 4th ed. AASHTO, 2005.

  This guidebook includes topics such as safety, design, location, preservation and restoration, visual quality, underground facilities and installation, overhead facilities, and ditches and canals.
- *Practitioner's Handbook #7: Defining the Purpose and Need, and Determining the Range of Alternatives for Transportation Projects,* 1st ed. AASHTO, 2007.

  This handbook provides guidance on how to define a project's purpose and need according to NEPA and determining the alternatives.

- Highway/Utility Issues. Course Number FHWA-NHI-134006.
  On completion of this two-day course, participants will be able to explain the importance of early involvement with utility-related activities, identify successful mitigation strategies, explain major impacts on schedule and cost, identify utility conflicts and develop a conflict matrix, and generate a resource toolkit for each of the major areas of project development.
- Real Estate Acquisition Under the Uniform Act: An Overview. Course Number FHWA-NHI-141045.
  On completion of this course, participants will be able to provide a basic overview of the Uniform Act; discuss the key elements of the act, develop an estimate of compensation through the appraisal process or waiver procedure, define the real estate acquisition process, identify relocation benefits and services, and list places to obtain relevant documents.
- Local Public Agency Real Estate Acquisition. Course Number FHWA-NHI-141047.
  This course provides an overview of the real estate acquisition authority and the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (Uniform Act) and related regulations.

4.8 TOOL 7: DETERMINE WORK PACKAGES AND SEQUENCING

Overview

Carefully designed work packages and sequences can increase project success possibilities. Projects suffer if work packages are determined without consideration of available funding sources, available contractor capabilities, and stakeholder concerns about project impacts. The work packages and sequence must be prepared by considering high-certainty funding sources, local contracting capabilities, available work force, bonding issues, procurement planning (division of internal and external work), road closure and detour options, road-user costs, and local access issues.

As Figure 4.10 shows, the need to determine work packages and sequencing arises primarily from complexity in the schedule and technical dimensions or from the interactions between them.

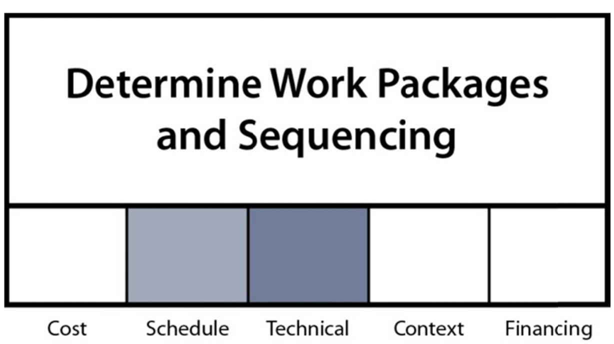


Figure 4.10. *Relationship of dimensions to Tool 7, determine work packages and sequencing.*

> "There is a definite, predictable relationship between cycle time, work in process, and production system throughput. It provides a pathway for further study of production system characteristics that have historically not been included in construction management models, with the expectation of developing new construction management tools that will account for more of the characteristics of construction production systems that affect project performance and company financial performance."
>
> *Bashford et al. (2005)*

In the context of the 5DPM model, complexity arises when the scope of the project is large or technical capabilities are significant, which suggests the need for multiple designers, contractors, and consultants.

If the schedule is also constrained or completion is critical because of high road-user costs or other schedule factors, interim schedule mileposts (such as opening and closing ramps) or turnover of work to designers or contractors in different phases creates potential negative impacts on the project. In these cases, use of thoughtful work packages that facilitate the sequence of design and construction work, coupled with frequent communication between all parties, will help achieve project success.

Work packaging to facilitate the sequence of work is recommended for complex projects when schedule and technical constraints make close coordination of work sequencing a requirement.

When to Determine Work Packages and Sequencing

Work packaging and sequencing spans several stages of the project life cycle. Begin implementation of this tool early in the planning phase as procurement for all services and construction is developed. Procurement, sequencing, and integration of work packages continue throughout completion of the project.

Readiness to Determine Work Packages and Sequencing

How does your organization prepare and develop work packages and design the sequence of work packages in the planning, scoping and programming, and preliminary engineering phases of project development?

- ☐ We do not consider in the planning, scoping and programming, or preliminary engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to develop work packages and their sequences, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in developing work packages and their sequences (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Determining Work Packages and Sequencing

After identifying complexity factors and completing Methods 1 through 5 (particularly procurement planning and project arrangements with Method 3), follow these steps to assign and sequence work packages:

1. Identify capabilities of the local suppliers, vendors, suppliers, contractors, and labor force. Determine the maximum level of each critical resource that is available during the project's execution period.
2. For externally procured work, develop work packages that can conform to local workforce and regional organizational capabilities. For internal work packages, make sure that adequate resources are available to be able to complete them in the time allotted.
3. Sequence work packages to facilitate seamless scheduling. Design work packages should lead directly to their associated construction work packages rather than be separated from the construction.
4. Include contract language in each work package to include coordination with upstream and downstream work.

Examples of Determining Work Packages and Sequencing

Detroit River International Crossing

For the DRIC project, the team developed a required project management plan that is updated periodically and used as a tool to summarize the project status and work plan. The team used internal Michigan DOT software to support financial and resource management, expenditures, and work activity management. Status reports were provided to senior leadership biweekly.

Doyle Drive

At the start, the Doyle Drive project in San Francisco, California, was planned to be one project. However, the estimated cost was too high, so not all the needed funds were available. The project was broken into eight contracts to accelerate the schedule.

I-95 New Haven Harbor Crossing Corridor

After finding no bidder for the original Pearl Harbor Bridge contract (because it was too complex and risky), the Connecticut DOT divided the project into smaller, simpler, and shorter contracts, which became the I-95 NHHCC program.

InterCounty Connector

Because of a political mandate for the InterCounty Connector projects in Maryland to finish in a compressed four-year time frame, the three active projects (Segments A, B, and C) were scheduled concurrently. The DB approach was used to fast-track the work sequence. The procurement started before planning was completed. Partial notices to proceed were issued to start design with pending environmental litigation and changing ROW requirements, which added to the complexity of work sequencing.

The InterCounty Connector team used a detailed work breakdown structure (WBS) to structure and sequence the work, which included field quality control, cost control, and project acceptance. The program manager developed a master schedule to sequence and track the entire program. (Primavera P6 software was specified at the project level.)

Because the projects were on a new alignment and performed concurrently, there was no need for interfaces between projects, and there were no incremental milestones in the schedules. The schedules were cost-loaded for payment purposes, P6-scheduled updates were required to be submitted biweekly, and narrative progress reports were submitted monthly to monitor progress. The projects also required weekly construction meetings and used three-week look-ahead schedules from the general contractors for short-term work package planning.

New Mississippi River Bridge

On the New Mississippi River Bridge project between Missouri and Illinois, there was a need to keep the project scope within available funding limits. Breaking the original project into "fundable" phases helped move the project forward. The scope flexibility in phasing the project into fundable packages was an effective tool for helping to manage project complexity.

Where to Learn More About Determining Work Packages and Sequencing

To learn more about determining work packages and sequencing, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP Project 25-25: Compendium of Best Practices for Incorporating Environmental Commitments into Transportation Construction and Maintenance Contract Documents*. 2009.
- *NCHRP 10-42: Constructability Review Process for Transportation Facilities*. 1996.
- *Constructability Review Best Practices Guide*. AASHTO, 2000.
- *Current Design–Build Practices for Transportation Projects*. FHWA, 2009.
- *NCHRP 20-07, Task 229: Bridge Construction Practices Using Incremental Launching*. 2007.

  This report contains the current state of the practice for the incremental launching method for bridge construction, as well as recommendations pertaining to best practices for planning, design, and construction activities. Applications and limitations are also provided.
- *NCHRP Report 652: Time-Related Incentive and Disincentive Provisions in Highway Construction Contracts*. 2010.

  This report offers best practices for using time-related incentives and disincentives. It covers the time of contract provisions used, the success of contract provisions, the criteria used to determine when provisions are appropriate, the methods used to determine dollar amounts on incentives and disincentives, and the effects on projects.

- *FHWA Guide for Construction Contract Time Determination Procedures*. 2002. This guide provides guidance on topics such as the elements in determining a contract time, establishing production rates, adapting production rates to a particular project, developing a progress schedule, contract time determination techniques, and other project considerations.

4.9 TOOL 8: DESIGN TO BUDGET

Overview

Complex projects often have complicated funding systems with fixed, finite appropriations that expire and must be disbursed within a specified time frame. In other cases, project elements are underwritten by debt instruments, or the entire project funding may not even be identified or secured. In these cases, designing within the known budget may be the only way to execute the project. However, designing to a fixed budget ceiling must fit the overall project strategy.

Consider use of project phasing and phased design and estimating to build the segments of the project that can be funded with currently available funding and innovative financing while keeping future overall project goals in mind. Also, consider stakeholder expectations in the process.

As Figure 4.11 shows, the need to design to budget arises primarily from complexity in the cost, technical, and financing dimensions or from the interactions among them.

In the context of the 5DPM model, designing to budget is based on the assumption that funding is constrained and the cost of the project must remain within the available funding. This constraint may require redesign, breaking the project into phases (Tool 7), or both, and suggests the need for strict cost control.

Technical requirements are made complex by the need to design current (funded) phases of the project to align with future phases that will be completed pending identification of funds. There may also be increased need for design exceptions.

Designing to budget has been found to be effective for complex projects when financing is constrained, cost control is possible without an impact on schedule, and there is flexibility in technical alternatives.

> "There are four issues that must be addressed in the internal design to budget process:
>
> 1. Communications between the designers and the owner's design reviewers
> 2. Developing design work packages that support the construction plan as well as the owner's design submittal schedule
> 3. Integrating preconstruction review input in the design schedule
> 4. Making all designers on the team aware of budget and schedule constraints."
>
> *Koch et al. (2010)*

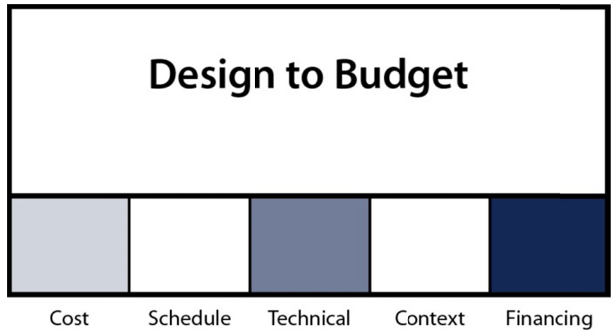


Figure 4.11. *Relationship of dimensions to Tool 8, design to budget.*

When to Design to Budget

You will need to decide to limit design options or reduce the initial project scope to conform to a constrained budget or schedule early in the planning process and communicate those limitations or reductions to designers before the start of significant design work. You also need to communicate any financing issues that threaten project feasibility to external stakeholders and the general public at the earliest discussions of the project so they are not taken by surprise if the project is reduced in scope or any nonessential design options (e.g., bike paths or artwork) are eliminated.

Readiness to Design to Budget

Does your organization consider designing the project within the budget or breaking the project into phases to meet the funding constraints during the planning, scoping and programming, and preliminary engineering phases of project development?

- ☐ We do not consider in the planning, scoping and programming, or preliminary engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to consider designing to budget, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in designing to budget (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Designing to Budget

From the results of the complexity identification and mapping process, as well as Methods 1 through 5, identify the cost and schedule constraints that necessitate designing the project to budget. Historically, design drives the budget, but as financing becomes an increasingly important aspect of project management, the opposite relationship holds true, and budget drives design.

This shift requires designers to be innovative. It is facilitated by the use of colocation of the design team with the owner and construction team (Tool 9) and flexible design criteria (Tool 10). Follow these steps in designing to budget:

1. Identify available funding and other cost and schedule constraints that affect design options; these constraints include project phasing, initial project scope, and restrictions on various sources of funding.
2. Establish maximum budget and schedule and develop design options intended to remain within those maximum values.
3. Confirm cost and schedule values early in the design process and update frequently to ensure that design and scope remain within the constraints. Look at alternative project delivery, early contractor involvement, or use of preconstruction service consultants to help achieve project success.
4. Use a tracking log for design exceptions required to maintain project cost and schedule and begin the approval process for design exceptions early. Communicate all requests for design exceptions early and track them.
5. Clearly communicate cost and schedule constraints and financing limitations to external stakeholder groups so that expectations for project outcomes or viability of other design options are managed appropriately.

Examples of Designing to Budget

Detroit River International Crossing

The DRIC project used Microsoft Project to create a project schedule that was based on team agreement of identified tasks, including resource and financial needs to complete the tasks.

New Mississippi River Bridge

On the New Mississippi River Bridge project between Missouri and Illinois, 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 cost and schedule risk-control mechanisms. 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.

T-REX

As with most DB projects, the contract on the T-REX project in Denver, Colorado, was set by the proposal amount, and the design-builder was obligated to provide a design that conformed with the contract amount. However, the owner did not specify a budget amount in advance.

Where to Learn More About Designing to Budget

To learn more about designing to budget, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP Report 390: Constructability Review Process for Transportation Facilities*. 1997.
  This project includes topics such as the current practice in constructability, critical issues in implementation, interpretation of current practice and critical issues, preliminary constructability review process model, formal constructability review process model, constructability review tools, and an implementation plan.
- *NCHRP 20-24(31): Research Program Design—Administration of Highway and Transportation Officials: Effective Program Delivery in a Constrained Fiscal Environment*. 2007.
  This report describes the forces of change and the impacts on program management and delivery and documents state-of-the-practice techniques used by state highway agencies to manage the process.
- *Guidelines for Value Engineering,* 3rd ed. AASHTO, 2010.
  This document provides guidelines for establishing and administering value engineering programs. It includes topics such as the elements of a state value engineering program, preconstruction value engineering for projects, construction value engineering, DB value engineering, and program management.
- *Effective Program Delivery in a Constrained Fiscal Environment,* 1st ed. AASHTO, 2009.
- Value Engineering Workshop. Course Number FHWA-NHI-134005.
  This three-day course covers topics such as how value engineering can improve project performance, reduce costs, and enhance value. Participants acquire the necessary skills to be an effective value engineering team member.
- *TCRP Web-Only Document 31 (Project G-7): Managing Capital Costs of Major Federally Funded Public Transportation Projects*. 2005.

4.10 TOOL 9: COLOCATE TEAM

Overview

Before the start of the project, discuss the advantages and disadvantages of project team colocation. Some compromise may be necessary, but having the whole team together most of the time may increase the odds of achieving critical project success factors.

> "Some fast-track projects have literally done away with formal design reviews and substituted collocated, over-the-shoulder design reviewers."
>
> *Koch et al. (2010)*

Particularly on multijurisdictional (e.g., bistate) projects, you may find placing a dedicated, empowered, representative project team in a common location important to project success. Depending on the project delivery system used, you may incorporate the colocation strategy for DB partners or the contracting team in later project stages.

As Figure 4.12 shows, the need to colocate the team is determined primarily by the technical dimension of the project.

When using the DB approach, cost and schedule complexity may also be factors in the decision to colocate, but they derive from the technical scope of the project. In the context of the 5DPM model, this tool is used because the technical complexity of the project makes it necessary (and justifies the cost of colocation) to maintain close communication between the owner, designers, and builder to guarantee that cost and schedule constraints are met.

Colocation is recommended for complex projects when technical complexity warrants the increased cost of colocation in return for improved cost and schedule controls.

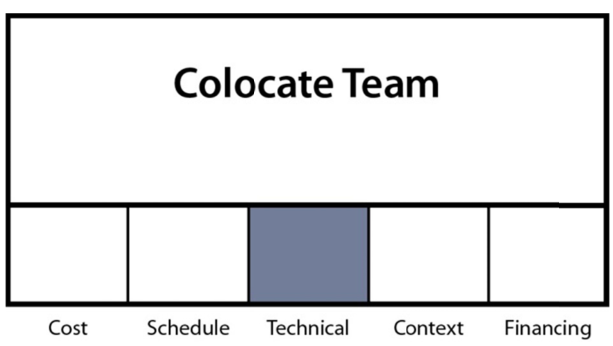


Figure 4.12. *Relationship of dimensions to Tool 9, colocate team.*

When to Colocate Team

You can use the colocation tool in planning, design, and construction, depending on the type of delivery system used and which project partners are colocated. Colocation is perhaps most likely to occur during the final design and construction phases.

Readiness to Colocate Team

How does your organization consider colocating project teams, depending on the project delivery system to be used, during the scoping and programming, preliminary engineering, and final engineering phases of project development?

- ☐ We do not consider in the scoping and programming, preliminary engineering, or final engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice)
- ☐ The project team is supposed to colocate project teams, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in colocating teams (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Colocating Team

Use the identification of complexity factors and the outcomes of Methods 1 through 5 to determine if colocation should be considered and to provide input into which members of the team to include in the colocation agreement. Integrate the use of the colocation tool with other tools, including comprehensive risk analysis (Tool 3), design to budget (Tool 8), and flexible design criteria (Tool 10). Follow these steps in collocating teams:

1. Identify the possible need for colocation and evaluate costs and benefits.
2. If colocation is warranted, identify which project team members should be included in the colocation.
3. Identify viable physical locations for colocation and arrange for necessary technology upgrades (e.g., voice or data lines, audio/visual, satellite, high-speed Internet) and space build-out (e.g., offices, conference rooms, storage).
4. Develop contractual agreements on payment for space improvements, lease payment, terms and duration of colocation, and other administrative details.

Examples of Colocating Team

I-95 New Haven Harbor Crossing Corridor

The Connecticut DOT established the NHHCC project headquarters in an independent building close to major project contracts and housed the program management firms in that office. According to project directors, this policy helped to create an effective team atmosphere for managing the project.

I-595 Corridor

Colocating all partners on the Florida DOT I-595 Corridor project in the same building was extremely helpful. The number of meetings and collaboration would have been very difficult without colocation.

New Mississippi River Bridge

On the New Mississippi River Bridge project between Missouri and Illinois, colocation of a dedicated, empowered project team enabled rapid design development and responsiveness to changes.

T-REX

The DB team on the T-REX project in Denver, Colorado, was colocated along with representatives from the owner's team. In this case, colocation allowed for sharing of information, facilitation of communications, ensuring the right mixture of skills, and partnering.

Where to Learn More About Colocating Team

To learn more about colocating project teams, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP Web Document 39: Managing Change in State Departments of Transportation. Scan 7 of 8: Innovations in Public–Private Partnering and Relationship Building in State DOTs*. 2001.
  This document examines successful partnerships and relationships and determines the common elements of success. It also provides a starting place for the development of new partnering tools.
- *NCHRP 20-24(22): Best Practices in Partnering with Public Resource Agencies.* 2003.
- *NCHRP 20-24(63): Partnership Approaches to Identify, Promote, and Implement Congestion Management Strategies*. 2009.
  This document summarizes the current knowledge about the relationships among transportation congestion, economic activity, economic growth, and transportation system investment at both the regional and national levels. It reviews congestion mitigation strategies that have been used and performs four case studies. Finally, it covers the lessons learned from effectively implementing congestion management practices.

- *AASHTO Partnering Handbook*, 1st ed. 2005.
  This handbook covers topics such as the partnering definition and the various roles in partnerships, the characteristics of successful partnerships, the partnering process, the partnering workshop, issue resolution, the importance of measuring a partnership, and how to showcase and celebrate a partnership.
- *Design-Build Environmental Compliance Process and Level of Detail: Eight Case Studies*. AASHTO, 2005.
- Partnering: A Key Tool for Improving Project Delivery in the Field. Course Number FHWA-NHI-134060.
  On completion of this course, participants will be able to integrate partnering at the project level, develop and implement control documents required in the partnering process, and guide other project personnel in integrating partnering at a project level.

4.11 TOOL 10: ESTABLISH FLEXIBLE DESIGN CRITERIA

Overview

Establishing flexible design criteria is closely related to project cost, schedule, and quality performance (e.g., designing to budget), as well as to critical permit issues. You can use flexible design criteria to help minimize potential ROW, utility, and U.S. DOT Section 4(f) conflicts. You can achieve flexible designs through the use of design exceptions, need-based review and approval processes, performance specifications, and mechanistic designs.

> "Develop flexible design criteria for roadways that provide for a range of design treatments that are context sensitive while satisfying fundamentals of roadway design, yet remain within the acceptable limits of AASHTO guidelines."
>
> *Bochner et al. (2004)*

Whenever possible, consider implementation of procurement protocols that allow designers to work with major material suppliers and vendors early in the project life cycle.

As Figure 4.13 shows, the need to establish flexible design criteria is determined primarily by the technical dimension of the project.

The best examples of establishing flexible design criteria may be renewal projects whose technical scope is too complex to establish contract documents effectively before construction. In these cases, performance specifications, qualifications-based DB selection, and use of design exceptions to reduce cost and shorten the schedule may facilitate project success.

Use of flexible design criteria is recommended for complex projects when technical complexity and constraints in other dimensions make standard designs and specifications impractical.

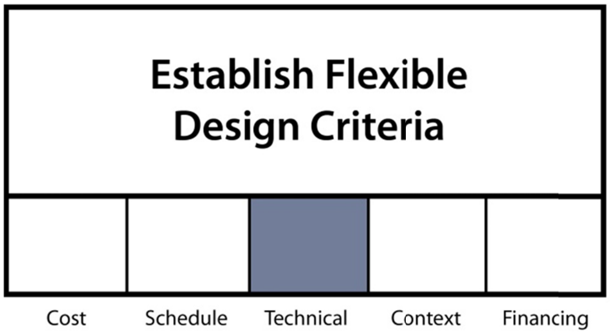


Figure 4.13. *Relationship of dimensions to Tool 10, establish flexible design criteria.*

When to Establish Flexible Design Criteria

Analyze use of design exceptions during the planning phase, and implement options throughout the design phase. Unless design exceptions are analyzed during planning, the flexible design criteria tool will provide little benefit or will make redesign necessary. To the extent possible, all exceptions should be completed before completion of the final design.

Readiness to Establish Flexible Design Criteria

Does your organization establish flexible design criteria in the scoping and programming and preliminary engineering phases of project development to minimize potential ROW, railroad, and utility conflicts by using design exceptions, need-based reviews, or performance specifications?

- ☐ We do not consider in the scoping and programming or preliminary engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to establish flexible design criteria, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in establishing flexible design criteria (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Establishing Flexible Design Criteria

Use the results of complexity identification and mapping, along with the outcomes of Methods 1 through 5, to provide guidance for establishing flexible design criteria. In addition, use the flexible design criteria tool to coordinate with identifying critical permit issues (Tool 4), evaluating applications of off-site fabrication (Tool 5), determining involvement in ROW and utilities (Tool 6), designing to budget (Tool 8), colocation (Tool 9), development of public involvement plans (Tool 13), and other tools as appropriate for your project. Follow these steps in establishing flexible design criteria:

1. Identify design constraints and locations of potential conflict (e.g., ROW, utility locations, historic neighborhoods, environmentally sensitive areas) that can be mitigated through alternative or innovative design approaches.
2. Catalog design exceptions required under each design option.
3. Articulate the rationale for design exceptions (e.g., use of performance specifications, mitigation of environmental impact, alleviation of ROW issues).
4. Set up a tracking and monitoring system to manage documentation, request, approval, and implementation of each design exception.

Examples of Using Flexible Design Criteria

Capital Beltway HOT Lanes

No design set could go to construction on the Capital Beltway HOT (high-occupancy toll) Lanes project in Virginia until approved by the owner. This arrangement provided control but maybe not enough control. Comments for each design were separated into three categories: preferred, reasonable or standard, and specified.

Detroit River International Crossing

An Executive Order required application of context-sensitive solutions principles on the Detroit River International Crossing project, so application of flexible design, public involvement, and enhanced mitigation or combinations of these factors were required. The aesthetic design guide for the project would implement the outcomes of the context-sensitive solutions 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 were incorporated into the final design and into construction.

The first phase of the aesthetic design guide is to define visual issues and impacts, goals and priorities, and conceptual aesthetic features and elements; the second phase generates design requirements and alternative design concepts and refines a preferred set of design elements for integration into the plans, specifications, and estimates. Separating design consultants based on distinct project limits, like scopes of services (such as freeway interchange design consultant, interchange bridge design consultant, aesthetic design guide consultant, value engineering consultant, and oversight consultant), will be a tool for flexible design.

I-95 New Haven Harbor Crossing Corridor

The Pearl Harbor Memorial Bridge, which is part of the NHHCC project, was the first extradosed bridge in the nation. The extradosed system could add to the complexity of the project from a technical point of view.

The extradosed system is a hybrid design that combines a box-girder bridge and a cable-stayed bridge to expand the span of the box girder. The extradosed main spans of the new Pearl Harbor Memorial Bridge were designed in both steel and concrete, allowing bidders to choose the least-cost alternative.

I-595 Corridor

When the Florida DOT made the decision to use design–build–finance–operate–maintain project delivery on the I-595 Corridor project, management recognized that for the project to be attractive to outside investment, design criteria had to be unconstrained wherever possible. In meeting that condition, management created an environment in which the concessionaire was able to balance life-cycle design issues with project pro forma requirements for the financing.

Where to Learn More About Establishing Flexible Design Criteria

To learn more about establishing flexible design criteria, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP 8-68: Citizen's Guide and Discipline-Specific Professionals' Guide for Context-Sensitive Solutions in Transportation*. 2010.
  This project developed two documents (one as a citizen's guide and one as a discipline-specific professional's guide) that explain the roles, responsibilities, and opportunities in transportation decision making from conception to operations and maintenance.
- *NCHRP Report 390: Constructability Review Process for Transportation Facilities*. 1997.
  This project includes topics such as the current practice in constructability, critical issues in implementation, interpretation of current practice and critical issues, preliminary constructability review process model, formal constructability review process model, constructability review tools, and an implementation plan.
- *NCHRP Report 703: Guide for Pavement-Type Selection*. 2011.
  This guide covers topics such as an overview of the pavement-type selection processes, identification of pavement alternatives and development of pavement life-cycle strategies, life-cycle cost analysis, selection of preferred pavement alternatives, alternate pavement-type bidding, and contractor-based pavement-type selection.
- *NCHRP Report 442: Systems Approach to Evaluating Innovations for Integration into Highway Practice*. 2000.
  This report provides an approach to evaluating innovations to determine if they should be integrated into current procedure. It looks at both qualitative and

quantitative information and at various innovations such as ground-penetrating radar, light-emitting diode traffic signals, and partnering. The use of the information in the report should result in higher-quality decisions.

- *Practitioner's Handbook #7: Defining the Purpose and Need, and Determining the Range of Alternatives for Transportation Projects,* 1st ed. AASHTO, 2007.
  This handbook provides guidance on how to define a project's purpose and need according to NEPA and determining the alternatives.

4.12 TOOL 11: EVALUATE FLEXIBLE FINANCING

Overview

Be sure to look at alternative funding sources to furnish the funds for a project when needed. If the cost, schedule, scope, and context represent relatively fixed and constrained factors, use of flexible financing may be the only option to advance the project.

As seen in Figure 3.8, several alternative funding sources are available, including the following:

- Tolling and other revenue-generation approaches (e.g., congestion pricing, HOT lanes)
- Transportation sales tax or other special taxes
- Project phasing to leverage different sources of financing
- Grant anticipation revenue vehicle bonds
- Transportation Infrastructure Finance and Innovation Act loans
- Hybrid forms of contracting such as public–private partnerships (PPPs) or various combinations of the design–build–operate–maintain–transfer approach
- Monetization of assets and service options, such as franchising

As Figure 4.14 shows, the need to evaluate flexible financing is determined primarily by the financing dimension of the project.

Use of flexible financing is recommended for complex projects when few viable technical alternatives exist, contextual constraints are significant, and cost or schedule parameters require the need to move forward (e.g., the problems will only get worse if the project is put on hold).

> "A Financial Plan is a comprehensive document that reflects the Project's cost estimate and revenue structure and provides a reasonable assurance that there will be sufficient financial resources available to implement and complete the project as planned."
>
> *FHWA (2007)*

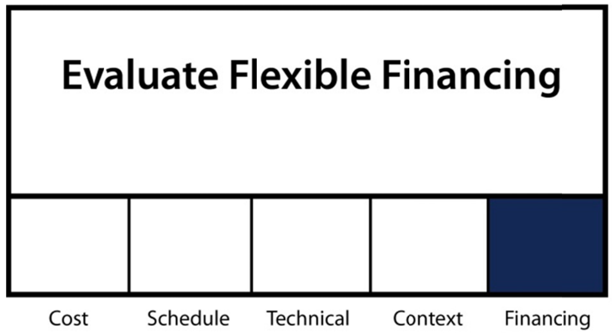


Figure 4.14. *Relationship of dimensions to Tool 11, evaluate flexible financing.*

When to Evaluate Flexible Financing

Ideally, begin evaluating flexible funding in the planning phase and complete it before design is finalized. If using project phasing to leverage financing, coordinate design packages with phasing and bid-letting schedules.

Readiness to Evaluate Flexible Financing

How does your organization evaluate alternative funding and financing sources in the planning, scoping and programming, and preliminary engineering phases of project development when the currently available funding is limited and the project cost, schedule, scope, and context represent relatively fixed and constrained factors?

- ☐ We do not consider in the planning, scoping and programming, or preliminary engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to consider and evaluate alternative funding and financing sources, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in evaluating alternative funding and financing sources (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Evaluating Flexible Financing

Use the results of complexity identification and mapping, along with the outcomes of Methods 1 through 5, to provide guidance for evaluating flexible financing. In addition, be sure to coordinate evaluation of flexible financing with designing to budget (Tool 8). Follow these steps in evaluating flexible financing:

1. Identify total expected project costs (planning, design, construction). These numbers should come from a comprehensive cost model that has been built specifically for this purpose.
2. Identify available funds from typical sources (state program, federal aid) and any time constraints that are associated with each.
3. Analyze any funding gaps.
4. Identify potential funding sources for gap financing, including debt and private equity, within state regulatory authority if possible.
5. If gap financing is inadequate for project funding, consider adding revenue-generating options such as congestion pricing, tolling, franchising, and so forth.

Examples of Using Flexible Financing

Capital Beltway HOT Lanes

An independent financing team was in charge of developing funding sources for the Capital Beltway HOT Lanes project in Virginia. An innovative project delivery group that focused on the technical aspects of the project worked with the financing team, which took a consulting role for the financing aspects.

Detroit River International Crossing

On the DRIC project, the owner solicited with a request for proposal of interest for market feedback, which was used to develop government policy and to structure a formal procurement process and needs for formal agreements with Canada.

Project development correlated directly with the mechanism chosen to finance the project. This was to pursue a PPP for the bridge and for either all or a portion of the plaza. One of the alternative funding methods considered was to have either the Michigan DOT 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.

Doyle Drive

On the Doyle Drive or Presidio Parkway project (one gateway to the Golden Gate Bridge in San Francisco, California), the government agreed to PPP, an innovative contracting method, to execute financial qualification.

I-595 Corridor

The Florida I-595 Corridor project is the first highway project in the United States to be delivered by the design–build–finance–operate–maintain method. This approach was attractive to the Florida DOT primarily because financing was available to the project, thus speeding up the construction schedule.

North Carolina Tollway

The North Carolina Tollway project used bonds for financing. Costs were in two parts: capital costs (covering construction and ROW) and operations and maintenance costs. Together, these costs made up the total cost, which was then taken to the bond market.

There were concerns about any cost overruns. The North Carolina DOT, through legislative action, agreed to pay for any cost overruns through the North Carolina Turnpike Authority. This agreement helped with the market rating on the bond market.

Where to Learn More About Evaluating Flexible Financing

To learn more about evaluating flexible financing, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP Research Results Digest 179: Financing Highway Improvements Through Public and Private Partnerships*. 1991.
- *NCHRP 8-57: Improved Framework and Tools for Highway Pricing Decisions*. 2009.
- *NCHRP Report 639: Guidelines for the Use of Pavement Warranties on Highway Construction Projects*. 2010.
- *NCHRP Web Document 121: Assessing and Mitigating Future Impacts to the Federal Highway Trust Fund Such as Alternative Fuel Consumption*. 2003.
- *NCHRP Report 623: Identifying and Quantifying Rates of State Motor Fuel Tax Evasion*. 2009.
- *NCHRP Report 689: Costs of Alternative Revenue-Generation Systems*. 2011.
- *NCFRP 3/NCHRP 185 Web-Only Document: Truck Tolling: Understanding Industry Trade-offs When Using or Avoiding Toll Facilities*. 2011.
- *NCHRP 20-24(07): Alternatives to the Motor Fuel Tax for Financing Surface Transportation Improvements*. 1994.
- *NCHRP 20-24(13): Innovative Financing Clearinghouse*. 2002.
- *NCHRP 20-24(51)C: State DOT Funding and Finance*. 2006.
- *NCHRP Report 341: Bond and Insurance Coverages for Highway Construction Contractors*. 1991.
- *Uniform Audit and Accounting Guide for Audits of Architectural and Engineering (A/E) Consulting Firms*. AASHTO, 2012.

  This guide presents topics such as the adequacy of accounting records, the standards for attestations and audits, cost principles, cost accounting, labor-charging systems and other considerations, compensation, information on selected areas of cost, general audit considerations, audit reports and minimum disclosures, and cognizance and oversight.

- *NCHRP Project 20-68A, Scan 07-01: Best Practices in Project Delivery Management*. 2009.
  The findings of this scan were that the best practices could be best divided into four focus areas: (1) project management, (2) performance measures, (3) contracting practices, and (4) community involvement. The scan provides detailed information in each of the four areas.

4.13 TOOL 12: DEVELOP FINANCE EXPENDITURE MODEL

Overview

For complex projects, you will need to obtain project cash flows and integrate them into project phasing plans to balance anticipated inflows and outflows of funds. You can use resource-loaded project plans and network schedules to track both expenditures and project cash needs. If cost, schedule, scope, and context represent relatively fixed and constrained factors, analyze the inflows and outflows of project funds, regardless of the source of funding.

> "A Financial Plan provides a description of how a project will be implemented over time by identifying project costs and the financial resources to be utilized in meeting those costs. The plan should clearly explain the assumptions about both cost and revenue upon which the plan is based."
>
> *FHWA (2007)*

As Figure 4.15 shows, the need to develop a finance expenditure model is determined primarily by the financing dimension of the project.

With or without flexible financing, you will need to track the pay request schedules of designers, consultants, and contractors against bond sales, appropriations, and other inflows of funds. You will need to establish and maintain minimum cash balances throughout the project as a source of contingency.

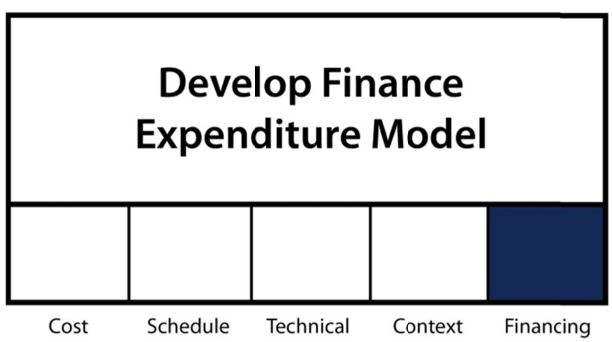


Figure 4.15. *Relationship of dimensions to Tool 12, develop finance expenditure model.*

Implement the finance expenditure model tool for complex projects when the project technical scope is large and fixed, project cost is closely equal to available funding, and few alternatives exist that would not substantially delay the project. In these circumstances, you will need to develop the model to maintain adequate cash balances. If, in any pay period, contextual constraints are significant and cost or schedule parameters require the need to move forward (e.g., the problems will only get worse if the project is put on hold), the financial expenditure model gives a statement of the resources available to solve the problem, which helps facilitate project success.

When to Develop Finance Expenditure Models

Develop and use a finance expenditure model as the planning process is completed and the project scope is well defined. Some information required for the finance expenditure model may not be available until the contractor has been selected.

For revenue-generating projects, your expenditure model may extend past the completion of construction and be modeled over the economic life of the project.

Readiness to Develop Finance Expenditure Models

How does your organization develop finance expenditure models in the planning, scoping and programming, and preliminary engineering phases of project development to manage and maintain adequate cash balances?

- ☐ We do not consider in the planning, scoping and programming, or preliminary engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).
- ☐ The project team is supposed to consider and develop a finance expenditure model, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in developing finance expenditure models (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Developing Finance Expenditure Models

Use the results of complexity identification and mapping, along with the outcomes of Methods 1 through 5, to provide guidance for developing a finance expenditure model. Coordinate use of the finance expenditure model tool with work packages and sequencing (Tool 7), designing to budget (Tool 8), evaluation of flexible financing

(Tool 11), and other tools as appropriate for your project. Follow these steps in developing finance expenditure models:

1. Identify timing of revenue inflows.
2. Use resource-loaded network schedules or earned-value analysis to identify projected cash outflows.
3. Aggregate inflows and outflows to common periods (probably end of month).
4. Analyze the finance expenditure model to identify cash balance shortfalls.
5. Develop protocols (e.g., maximum draw schedules, short-term borrowing, contractor-financed phases) to manage cash balance shortfalls.

Examples of Developing Finance Expenditure Models

Capital Beltway HOT Lanes

The Capital Beltway HOT Lanes project used concession-funded legislation, which means a private partner gave money ($6 million for the Virginia DOT development costs and $15 million for traffic enhancements) in the project development phase and would generate revenue from tolls later. Using these funds required special legislation. Private-sector money had to be obtained in advance and placed in a fund to ensure that Virginia DOT could make payments.

I-95 New Haven Harbor Crossing Corridor

Each of the NHHCC projects was scheduled according to availability and the cash flow distribution of the federal assistance for the project. This constraint caused the Connecticut DOT to rearrange and package projects in a manner that was compatible with the availability of federal funds rather than other constraints, such as expediency.

I-595 Corridor

The original finance expenditure model for the Florida DOT I-595 Corridor project proved that the funding necessary to accommodate future growth on the project would not be available in a reasonable time frame or in sufficient amounts over time. Therefore, the finance expenditure model was used as justification to move the project to design–build–finance–operate–maintain project delivery.

InterCounty Connector

Bond money was separated, so it was not used on nonpublic InterCounty Connector projects in Maryland. Ballpark estimates were used for in-house personnel on private-owner projects. Based on bond money and estimates, an expenditure model was developed. Some projects were charged according to the expenditure model.

North Carolina Tollway

The design-builder was required to have a cost-loaded critical path method schedule on the North Carolina Tollway. This schedule was updated every two weeks. The activities within this schedule could not exceed 20 days or $500,000 (with a few exceptions, such as a bridge deck pour). There were more than 3,000 activities, each with its own cost curve, and this was the basis of payment.

Where to Learn More About Developing Finance Expenditure Models

To learn more about developing finance expenditure models, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *Uniform Audit and Accounting Guide for Audits of Architectural and Engineering (A/E) Consulting Firms*. AASHTO, 2012.
  This guide presents topics such as the adequacy of accounting records, the standards for attestations and audits, cost principles, cost accounting, labor-charging systems and other considerations, compensation, information on selected areas of cost, general audit considerations, audit reports and minimum disclosures, and cognizance and oversight.
- *The Forum on Funding and Financing Solutions for Surface Transportation in the Coming Decade Conference Report*. AASHTO, 2011.
- *Use of Advance Construction in Financing Transportation Projects*. AASHTO, 2011.
- *Innovative Transportation Financing Report,* 1st ed. AASHTO, 1995.
  This document offers an overview of the financing methods used by various state agencies and provides an overview of the legislation used in those states.
- AASHTO Center for Excellence in Project Finance. http://www.transportation-finance.org/.
- *NCHRP Project 20-68A, Scan 07-01: Best Practices in Project Delivery Management*. 2009.
  The findings of this scan were that the best practices could be divided into four focus areas: (1) project management, (2) performance measures, (3) contracting practices, and (4) community involvement. The scan provides detailed information in each of the four areas.
- *NCHRP Synthesis 442: Practices and Performance Measures for Local Public Agency Federally Funded Highway Projects*. 2013.
- *NCHRP Report 694: Evaluation and Performance Measurement of Congestion Pricing Projects*. 2012.
- *FHWA: Financial Plans Guidance*. 2007.

4.14 TOOL 13: ESTABLISH PUBLIC INVOLVEMENT PLANS

Overview

Stakeholder needs and concerns are frequently the driver in developing design options and project delivery methods on many complex projects. Extensive public outreach is required for project success, particularly for complex renewal projects.

Implement public involvement planning early in the planning phase to help mitigate public disruption (such as with self-detour planning) and dissatisfaction. Consider retaining public relations specialists to serve as points of contact. Also, consider holding neighborhood or community meetings with open agendas and mechanisms to solicit feedback. Develop your public communication plans very early in the planning process.

> Stakeholder management is "the continuing development of relationships with stakeholders for the purpose of achieving a successful project outcome."
>
> *McElroy and Mills (2003)*

As Figure 4.16 shows, the need to establish public involvement plans is determined primarily by the context dimension of the project.

If context uncertainty or complexity creates a potential impact on cost and schedule factors, consider the use of public involvement plans to manage the process of external communication and management of expectations. If using innovative financing, public involvement plans can be useful in educating the public about the new methods employed on the project.

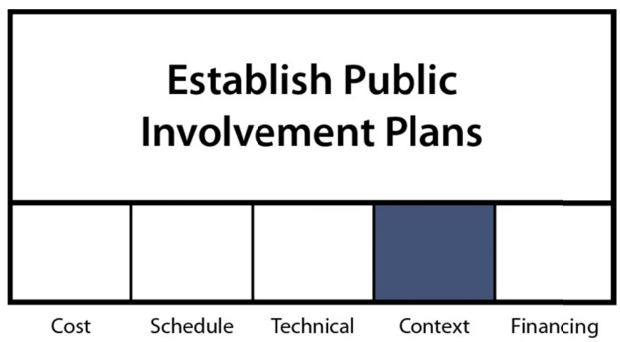


Figure 4.16. *Relationship of dimensions to Tool 13, establish public involvement plans.*

When to Establish Public Involvement Plans

Begin planning for public involvement at the earliest stages of the project and continue with implementation through completion of construction.

Readiness to Establish Public Involvement Plans

How does your organization establish public involvement plans such as neighborhood meetings and public communications in the planning, scoping and programming, preliminary engineering, and final engineering phases of project development to mitigate public disruption and dissatisfaction?

- ☐ We do not consider in the planning, scoping and programming, preliminary engineering, or final engineering phases of project development (novice).
- ☐ The project team may use its own judgment or hire a subject matter expert (above novice).

- ☐ The project team is supposed to consider and establish public involvement plans, but the process is not well defined and may vary from project to project (in between with buy-in).
- ☐ We have a standard and documented process or tool in establishing public involvement plans (some maturity or experience).
- ☐ In addition to Item 4 above, we have a system for the feedback and lessons learned by collecting relevant information after the project is completed to continuously improve the process (mature or experienced).

Table 2.2 (in Section 2.2) provides recommendations, depending on your answer.

Steps in Establishing Public Involvement Plans

Use the results of complexity identification and mapping, along with the outcomes of Methods 1 through 5 (particularly Method 5), to provide guidance for establishing public involvement plans. Coordinate your public involvement planning with comprehensive risk analysis (Tool 3), critical permit issues [specifically, U.S. DOT Section 4(f) issues] (Tool 4), and evaluation of off-site fabrication (Tool 5). Follow these steps in establishing public involvement plans:

1. Identify key public stakeholders (from comprehensive risk analysis) and road users affected by the project.
2. Set up communication and information-sharing systems (e.g., public meetings, websites, newsletters, web cams, 411 phone links, mobile alerts, dynamic message boards).
3. Gather information on specific public stakeholder concerns and relay information to the project team (e.g., designers, builders, consultants).
4. Report back. The key to successful public involvement plans is frequent, targeted communication that is responsive to the concerns of public stakeholders. Be sure to design follow-up communications to address concerns raised in Step 3 or a rationale (such as budget constraints, funding limits) to explain why public concerns cannot be addressed.

Examples of Using Public Involvement Plans

Capital Beltway HOT Lanes

For the Capital Beltway HOT Lanes project, a communications and outreach plan was developed and a public communication line was maintained 24 hours a day, seven days a week. Knowing that public expectations were high, the Virginia DOT guaranteed to respond at any time of the day. To build positive relations with the local community, the Virginia DOT maintained one of the largest public information teams in the state and sponsored and supported many civic events to help build and ensure trust.

Open, timely communication and a commitment to promises were the best response to political concerns or inquiries. Having a direct line to the secretary of transportation was effective in moving the project along and managing information for the sake of political involvement. The Virginia DOT responded to political requests with communication and by fulfilling promises.

From the owner's point of view, decision making from lower-level personnel for matters at a much higher level served as an effective tool. More authority was given to lower-level personnel in managing mega projects on the Capital Beltway HOT Lanes project.

Detroit River International Crossing

For the DRIC project, an aggressive public involvement plan was developed from the required application of context-sensitive solutions principles from an Executive Order. Nearly 100 public meetings, hearings, and workshops were held to facilitate public involvement. The methods used and information presented were guided by public involvement plans established at the outset of the project and refined as the project unfolded.

Access to the study through a toll-free project hotline and written comments through the project website or by mail were available and encouraged through the study process. A DRIC Study Information Office was open to provide information and answer questions about the project.

Approximately 10,000 residences and businesses received mailings about each formal public meeting. In addition to the mailings, more than 1,000 fliers were delivered door-to-door for public meetings and workshops.

A local advisory committee was established to provide a focused opportunity for feedback on the project. The team also arranged private-sector forums to provide an overview of the project and updates, as well as a complete overview package, which included frequently asked questions and answers, describing the project.

As legislatively mandated, the Michigan DOT performed an investment-grade traffic study that provided traffic data to refine the purpose and need for the project and validate funding needs and revenue opportunities.

InterCounty Connector

The InterCounty Connector projects in Maryland incorporated extensive public outreach and public input. Visual models of design ideas were created for public viewing, and there was an interagency working group to establish public relationships. Extensive coordination was executed to streamline resolution of potential environmental issues.

I-95 James River Bridge

An early public information plan was used that included a community advisory panel, dialogue with Interstate truckers, and variable message signs before design. The public information plan was implemented as soon as the need for communications was defined.

Where to Learn More About Establishing Public Involvement Plans

To learn more about establishing public involvement plans, see the associated SHRP 2 R10 training materials, which are available at www.trb.org/Main/Blurbs/167482.aspx.

The following resources are also available for more in-depth information:

- *NCHRP 8-40: Evaluating Cultural Resource Significance Using Information Technology,* 2002.

  This research was used to develop a range of options and solutions to improve decision-making procedures in transportation agencies. Solutions and options include the "do nothing" alternative, non–information technology solutions (e.g., training, guidelines, and procedures), and information technology solutions (e.g., improvement of data collection and management, improvement of data accessibility, development of knowledge management, and decision-support tools).
- *NCHRP 8-65: Guidebook for Successful Communication, Cooperation, and Coordination Between Transportation Agencies and Tribal Communities.* 2010.

  This guidebook summarizes the current practices of the efforts used to involve tribal communities in transportation planning and project implementation. The report goes on to determine which strategies are the most effective for communication and collaboration between transportation agencies and tribal communities.
- *NCHRP Report 710: Practical Approaches for Involving Traditionally Underserved Populations in Transportation Decision Making.* 2012.

  This report details the patterns, trends, and factors driving change across the United States. It examines practical approaches to involving underserved populations and provides effective practices, tools, and techniques and use of data sources and tools to best involve underserved populations.
- *NCHRP Report 364: Public Outreach Handbook for Departments of Transportation.* 1994.

  This project report covers topics such as principles of communications, the six steps to strategic communications planning, public finance, and applying principles to practice.
- *NCHRP 20-24(51)B: Building Credibility with Customers/Stakeholders.* 2006.
- *NCHRP 20-24(62): Communication Strategies to Increase Understanding of Funding and Revenue Needs for the Nation's Transportation System.* 2010.

  This report covers the first phase of the project and covers topics such as the essential guide for senior staff, the tactical toolkit, and the lessons learned from several case studies.
- *NCHRP 20-24(62)A: Communication Strategies to Enhance Public Understanding of Highway and Transit Program Funding Needs.* 2010.
- *NCHRP Report 487: Using Customer Needs to Drive Transportation Decisions.* 2003.

  This report includes topics such as a rationale for customer needs analysis, customer grouping and segmentation, choice of data-gathering techniques, applying customer needs to decision making, nontransportation best practices, transportation best practices and implementation strategies, case studies of customer analysis in agency work, guidelines for practitioners, and the potential for information sharing.

- *NCHRP Synthesis of Highway Practice 407: Effective Public Involvement Using Limited Resources*. 2010.
  This synthesis includes a literature review and a survey of 26 public agencies to determine the best practices (tools and techniques) used and examples of their use. The four main subareas that were consistent in all the agencies were organizational structure, staffing, cost quantification, and the process with regard to public involvement.
- *NCHRP Synthesis of Highway Practice 413: Techniques for Effective Highway Construction Projects in Congested Urban Areas*. 2011.
  This study focused on the techniques used by agencies to effectively deal with high traffic volume, significant utility conflicts and relocations, complex ROW acquisition actions, a diverse stakeholder base, and attentive media markets. The study identified the strategies, determined how agencies rated their success, and examined the applicability of the strategies to other projects.
- *Practitioner's Handbook #5: Utilizing Community Advisory Committees for NEPA Studies,* 1st ed. AASHTO, 2007.
  This handbook provides the key issues to consider and the practical tips to use when determining whether to employ a community advisory committee. Some of the practical tips include items such as potential members, selection process, defining the community advisory committee's role, rules for participation, logistics, cost, and timing and scope of committee involvement.
- Public Involvement in the Transportation Decisionmaking Process. Course Number FHWA-NHI-142036.
  By the end of this three-day course, participants will be able to describe U.S. DOT decision-making processes, the relationship between the public and decision making, develop a public involvement plan, describe interest-based problem solving, and identify ways to enhance public involvement plans.
- Effective Communications in Public Involvement. Course Number FHWA-NHI-142059.
  On the completion of this six-hour course, participants will be able to define values, interests, and needs (VIN); identify common problems that develop when the VIN is not understood; communicate through the public's VIN; develop a communications plan and incorporate the public VIN into the plan; develop a plan for a public meeting; make an effective presentation; describe facilitation techniques to accomplish meeting goals; and describe a process for dealing with hostile groups.

ALPHABETICAL GLOSSARY

This alphabetical glossary provides definitions for factors that affect project complexity. Many of these definitions were adapted from other sources. A glossary that is alphabetical for each of the five dimensions follows this one.

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.

automation. The use of automated or robotic equipment for construction.

bond funding. The floating of bonds that 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 in order to undertake current projects.

carbon credit sales. The carbon stored by trees and plants has a market value calculated as credits that can be sold to help finance the project.

construction quality. The value of the work that is being put in place by the contractors.

contingency usage. The reserve budget or budgets (either allocated or unallocated) that are added to the overall cost estimate to account for unknown risks.

contract formation. The development of the contract responsibilities and specifications.

cordon or 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.

cost control. All the tools and methods used to control and manage costs throughout the project.

cultural impacts. The culture or cultures of the area and their possible impact on the project.

delivery methods. The type of contracting approach used and how it is set up.

demographics. Outline of the distribution of the population within an area. Alignment decisions may affect different demographics.

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 lifespan.

disputes. Disagreements between the parties and how they are to be handled.

earned-value analysis. The tracking of scheduled work versus actual work performed.

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.

estimate formation. All the different kinds of estimates required and the susceptibility to those costs varying from initial to final estimates.

existing conditions. Any structural limitations already in place that need to be accounted for in the design to satisfy the solution required by the owner.

federal funding. Provided by the national government, it is standard across the nation and is derived from the annual transportation bill.

financial management software. Any software used for managing the financial aspects of a project.

force majeure events. Catastrophic events such as tornado, hurricane, or terrorism.

franchising. When private companies are offered the opportunity, they build and operate income-producing facilities such as rest areas or fuel stations on the public right-of-way in return for a portion of the profits.

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 a positive or negative impact on the project.

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.

growth inducement. A potential project may spur growth.

incentive usage. The use of incentives by the owner for early completion of the project.

intelligent transportation systems. Smart traffic systems for transportation projects for which user needs are analyzed and integrated into the implementation of a project.

intermodal. More than one mode of transportation, and a factor that must be recognized when planning projects that involve or affect other modes of transportation.

jurisdictions. An all-encompassing group that includes any local, state, or federal organizations, such as metropolitan planning organizations, the State Historic Preservation Office, or FHWA. These entities may become involved because of regulations and limitations encountered on the project.

land acquisition. Acquisitions may be hindered by the ability to acquire and the process of acquiring the portions of land necessary for the project.

land use impact. A potential project may alter potential land use or the zoning plan of the area.

legislative process. The legal limitations placed on financing methods.

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.

local economics. Influenced by growth inducement, alterations to land use, rerouting of traffic away from business districts, and creation of jobs, directly or indirectly.

local workforce. The skill and ability of the workers and the number of qualified entities that can fulfill the project requirements.

maintaining capacity. Planning decisions made by the owner, such as lane closures, detours, and time of construction activities (e.g., nighttime, weekends).

marketing. Notification of the public of the project and its progress, particularly the aspects that have a direct impact on the public.

material cost issues. The probability of the material costs changing due to market volatility.

milestones. Important deadlines during the project life cycle and occurrence of these events in a timely manner.

monetization of existing assets. An existing asset (e.g., a road or bridge) will be 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.

optimization impact on construction quality. Trade-off between cost, schedule, and quality (e.g., increasing quality requirements may increase costs).

optimization impact on project cost. Trade-off between cost, schedule, and quality (e.g., reducing the duration of the project typically comes with a higher cost).

optimization impact on project schedule. Trade-off between cost, schedule, and quality (e.g., accelerating the schedule may affect quality).

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 failure or success.

owner resource cost allocation. The distribution of costs by the owner internally to make sure each area of project management has adequate finances to perform its operations.

owner's internal structure. How the owner is set up to effectively manage the project (e.g., traditional hierarchy, matrix with project teams).

payment restrictions. The ability of the owner to pay for performed work, such as accelerated work performed by the contractor.

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.

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.

procedural law. The legal channels and limitations that should be followed for implementation of a transportation project 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.

project manager financial training. The education necessary for project managers to understand financial methods.

project scope. The purpose of the project and what is going to be built to satisfy that purpose.

public. Directly affected by and has the potential to affect the project from initial conception through completion and well after turnover. The transportation project is for the public and its interests.

public emergency services. Includes services that may need to be altered, such as emergency routes taken by fire and medical personnel.

public–private partnerships. Requires both public and private financing. The overall purpose for this category is to gain public access to private capital and create a situation in which the developers' capital is able to bridge the funding gap in a much-needed piece of infrastructure and thus accelerate the delivery of its service to the traveling public.

railroad coordination. The coordination between the railroad agencies and the project.

resource availability (context). Availability of materials, labor, and equipment because of external factors (affected not because of cost, but scarcity).

resource availability (schedule). The availability and uniformity of resources needed to maintain or alter the schedule.

revenue generation. Any type of financing that is paid for by a generation of revenue from the infrastructure over a specified time period.

reviews and analysis. Methods for maintaining accuracy and quality of the design that include tools such as value engineering and analysis and constructability reviews.

risk analysis (cost). Cost risk associated with a project that cannot be clearly identified and quantified through formal or informal analysis.

risk analysis (financing). Formal or informal analysis that the financing methods play on the project.

risk analysis (schedule). Schedule risk associated with a project that cannot be clearly identified and quantified through formal or informal methods.

safety and health. Maintaining a workplace (by all parties) where workers feel comfortable.

schedule control. All the tools and methods used to control and manage the schedule throughout the project.

scheduling system and software. The different types of systems and software available and mandated for the project, all with different capabilities.

social equity. Maintaining equality between all social classes that use and are affected by the project.

state funding. Independently financed through the particular state in which the project is taking place.

sustainability goals. Materials or requirements to use environmentally friendly construction materials or desires by the owner to use alternative materials or methods.

technology usage. The technology specified to be used for project communications, such as specific project management software, building information modeling, and others.

timeline requirements. The timeline of the project (e.g., accelerated).

transition toward alternative financing sources. The financing of complex projects compared to traditional project financing and the shift in financial planning.

typical climate. The typical climate where the project is located and the construction limitations presented by the area's typical climatic conditions.

unexpected weather. Unforeseen conditions that are abnormal to typical conditions and therefore cannot be planned around.

uniformity restrictions. The consistency seen between states in legislation and financing techniques.

use of commodity-based hedging. The ability to lock in the material price at the earliest point when the required quantity is known.

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.

utility coordination. All the services necessary that may need to be moved and coordinated (e.g., electricity, gas).

vehicle miles traveled fees. User fees that charge the driver a specific cost for using the infrastructure.

warranties. Provided by contractors who ensure the quality and guarantee that pieces of the project will remain adequate for a specified time period.

work breakdown structure. The breakdown of the roles and responsibilities delegated to project participants.

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.

GLOSSARY BY DIMENSION

This glossary, which is alphabetical for each of the five dimensions, provides definitions for factors that affect project complexity. Many of these definitions were adapted from other sources.

CONTEXT DIMENSION

cultural impacts. The cultures of the area and their possible impacts on the project.

demographics. Outline of the distribution of the population within an area. Alignment decisions may affect different demographics.

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.

force majeure events. Catastrophic events such as tornado, hurricane, or terrorism.

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 a positive or negative impact on the project.

growth inducement. A potential project may spur growth.

intermodal. More than one mode of transportation, and a factor that must be recognized when planning projects that involve or affect other modes of transportation.

jurisdictions. An all-encompassing group that includes any local, state, or federal organizations, such as metropolitan planning organizations, the State Historic Preservation Office, or FHWA. These entities may become involved because of regulations and limitations encountered on the project.

land acquisition. Acquisitions may be hindered by the ability to acquire and the process of acquiring the portions of land necessary for the project.

land use impact. A potential project may alter potential land use or the zoning plan of the area.

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.

local economics. Influenced by growth inducement, alterations to land use, the rerouting of traffic away from business districts, and the creation of jobs, directly or indirectly.

local workforce. The skill and ability of the workers and the number of qualified entities that can fulfill the project requirements.

maintaining capacity. Planning decisions made by the owner, such as lane closures, detours, and time of construction activities (e.g., nighttime, weekends).

marketing. Notification of the public of the project and its progress, particularly the aspects that have a direct impact on 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 failure or success.

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.

procedural law. The legal channels and limitations that should be followed for implementation of a transportation project 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.

public. Directly affected by and has the potential to affect the project from initial conception through completion and well after turnover. The transportation project is for the public and its interests.

public emergency services. Includes services that may need to be altered, such as emergency routes taken by fire and medical personnel.

railroad coordination. The coordination between the railroad agencies and the project.

resource availability. Availability of materials, labor, and equipment because of external factors (affected not because of cost, but scarcity).

social equity. Maintaining equality between all social classes that use and are affected by the project.

sustainability goals. Materials or requirements to use environmentally friendly construction materials or desires by the owner to use alternative materials or methods.

unexpected weather. Unforeseen conditions that are abnormal to typical conditions and therefore cannot be planned around.

utility coordination. All the services necessary that may need to be moved and coordinated (e.g., electricity, gas).

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.

COST DIMENSION

contingency usage. The reserve budget or budgets (either allocated or unallocated) that are added to the overall cost estimate to account for unknown risks.

cost control. All the tools and methods used to control and manage costs throughout the project.

estimate formation. All the different kinds of estimates required and the susceptibility to those costs varying from initial to final estimates.

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.

optimization impact on project cost. Trade-off between cost, schedule, and quality (e.g., reducing the duration of the project typically comes with a higher cost).

owner resource cost allocation. The distribution of costs by the owner internally to make sure each area of project management has adequate finances to perform its operations.

payment restrictions. The ability of the owner to pay for performed work, such as accelerated work performed by the contractor.

risk analysis. Cost risk associated with a project that cannot be clearly identified and quantified through formal or informal analysis.

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.

FINANCING DIMENSION

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.

bond funding. The floating of bonds that 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 in order to undertake current projects.

carbon credit sales. The carbon stored by trees and plants has a market value calculated as credits that can be sold to help finance the project.

cordon or 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.

federal funding. Provided by the national government, it is standard across the nation and is derived from the annual transportation bill.

financial management software. Any software used for managing the financial aspects of a project.

franchising. When private companies are offered the opportunity, they build and operate income-producing facilities such as rest areas or fuel stations on the public right-of-way in return for a portion of the profits.

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.

legislative process. The legal limitations placed on financing methods.

monetization of existing assets. An existing asset (e.g., a road or bridge) will be 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.

project manager financial training. The education necessary for project managers to understand financial methods.

public–private partnerships. Requires both public and private financing. The overall purpose for this category is to gain public access to private capital and create a situation in which the developers' capital is able to bridge the funding gap in a much-needed piece of infrastructure and thus accelerate the delivery of its service to the traveling public.

revenue generation. Any type of financing that is paid for by a generation of revenue from the infrastructure over a specified time period.

risk analysis. Formal or informal analysis that the financing methods play on the project.

state funding. Independently financed through the particular state in which the project is taking place.

sustainability goals. Materials or requirements to use environmentally friendly construction materials or desires by the owner to use alternative materials or methods.

transition toward alternative financing sources. The financing of complex projects compared to traditional project financing and the shift in financial planning.

uniformity restrictions. The consistency seen between states in legislation and financing techniques.

use of commodity-based hedging. The ability to lock in the material price at the earliest point when the required quantity is known.

vehicle miles traveled fees. User fees that charge the driver a specific cost for using the infrastructure.

SCHEDULE DIMENSION

earned-value analysis. The tracking of scheduled work versus actual work performed.

milestones. Important deadlines during the project life cycle and occurrence of these events in a timely manner.

optimization impact on project schedule. Trade-off between cost, schedule, and quality (e.g., accelerating the schedule may affect quality).

resource availability. The availability and uniformity of resources needed to maintain or alter the schedule.

risk analysis. Schedule risk associated with a project that cannot be clearly identified and quantified through formal or informal methods.

schedule control. All the tools and methods used to control and manage the schedule throughout the project.

scheduling system and software. The different types of systems and software available and mandated for the project, all with different capabilities.

timeline requirements. The timeline of the project (e.g., accelerated).

work breakdown structure. The breakdown of the roles and responsibilities delegated to project participants.

TECHNICAL DIMENSION

automation. The use of automated or robotic equipment for construction.

construction quality. The value of the work that is being put in place by the contractors.

contract formation. The development of the contract responsibilities and specifications.

delivery methods. The type of contracting approach used and how it is set up.

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 lifespan.

disputes. Disagreements between the parties and how they are to be handled.

existing conditions. Any structural limitations already in place that need to be accounted for in the design to satisfy the solution required by the owner.

intelligent transportation systems. Smart traffic systems for transportation projects for which user needs are analyzed and integrated into the implementation of a project.

optimization impact on construction quality. Trade-off between cost, schedule, and quality (e.g., increasing quality requirements may increase costs).

owner's internal structure. How the owner is set up to manage the project effectively (e.g., traditional hierarchy, matrix with project teams).

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.

project scope. The purpose of the project and what is going to be built to satisfy that purpose.

reviews and analysis. Methods for maintaining accuracy and quality of the design that include tools such as value engineering and analysis and constructability reviews.

safety and health. Maintaining a workplace (by all parties) where workers feel comfortable.

technology usage. The technology specified to be used for project communications, such as specific project management software, building information modeling, and others.

typical climate. The typical climate where the project is located and the construction limitations presented by the area's typical climatic conditions.

warranties. Provided by contractors who ensure the quality and guarantee that pieces of the project will remain adequate for a specified time period.

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A CASE STUDY SUMMARIES

The researchers investigated 15 projects in the United States and three international projects through in-depth case studies to identify tools that aid complex-project managers to deliver projects successfully. These 18 projects represent various project types, locations, project sizes, and phases of project development.

The case study summaries are presented in alphabetical order by the name used for each project by the researchers. Each case study summary includes a project overview, project complexity details (including a complexity map or radar diagram), and a paragraph listing the primary methods and tools used for the project.

CAPITAL BELTWAY

Project Overview

The Capital Beltway project is a complex project in northern Virginia consisting of 14 mi of four high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes, lane connections, construction or reconstruction of 11 interchanges, and replacement or improvements of 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 to $2.4 billion.

Project planning 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.

Project Complexity

The Capital Beltway HOV/HOT Lanes Project was delivered by PPP with the design–build (DB) method. The Virginia Department of Transportation (DOT) mega-project team had previous experience with DB, but there was still some unfamiliarity, which 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 challenging task for intelligent transportation systems personnel. There were many technical factors to consider, such as pass type (electronic pass, no pass, or both), how to recognize the number of people in the vehicles, how to distinguish animals or "dummy" passengers from human passengers, and many other technical issues.

In addition to the technical matters, laws needed to be considered to ensure the developed system was not illegal. For example, the legal issues involving use of photos for toll enforcement needed investigation before application.

Different sources of funding and atypical financing processes related to the PPP were challenging. The complexity diagram in Figure A.1 shows the dimensional complexity scores that interviewees provided.

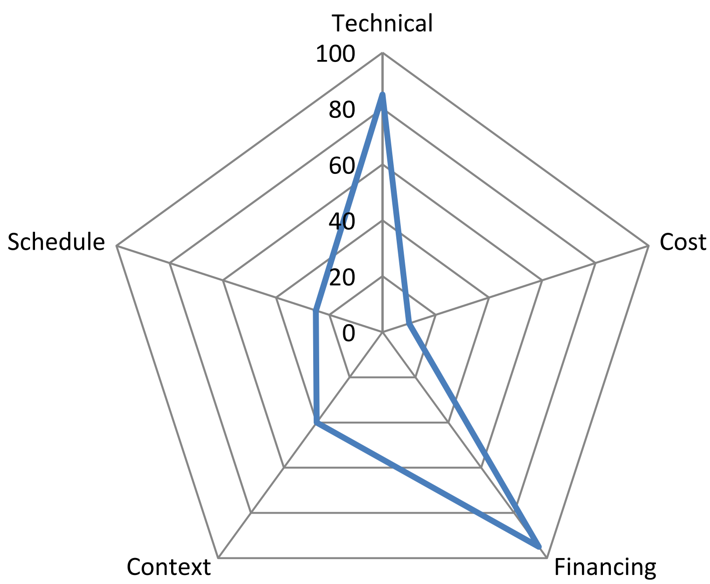

Figure A.1. *Capital Beltway complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include assembling project team, preparing early cost model and finance plan, and establishing public involvement plans.

DETROIT RIVER INTERNATIONAL CROSSING

Project Overview

The purpose of the project is to provide a new Detroit River International Crossing (DRIC) connecting Detroit, Michigan, with Windsor, Ontario, Canada. This bridge would complement an existing, privately owned, 81-year-old toll bridge (Ambassador Bridge) and an existing 80-year-old tunnel (the Detroit–Windsor Tunnel) that has usage limitations for commercial vehicles. The project will also provide a freeway-to-freeway connection between I-75 in Detroit and Highway 401 in Windsor.

The overall project has 10 primary components and various funding sources associated with each component. The project is needed to provide redundancy for mobility and trade between the two countries, support economies by connecting the major freeways, and support civil, national defense, and homeland security emergency needs.

Project Complexity

Multiple agencies are involved in the project (the Michigan DOT and the Federal Highway Administration in the United States and the Ontario Ministry of Transportation and Transport Canada in Canada), and separate documents are required for each country. Multiple stakeholders showed interests and involvement in each country. Project funding is from multiple sources, including tolling.

Political issues also made this project complex, as shown in Figure A.2. Those issues included a 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 of the delivery. Projected financial cost for the project is more than $1.8 billion.

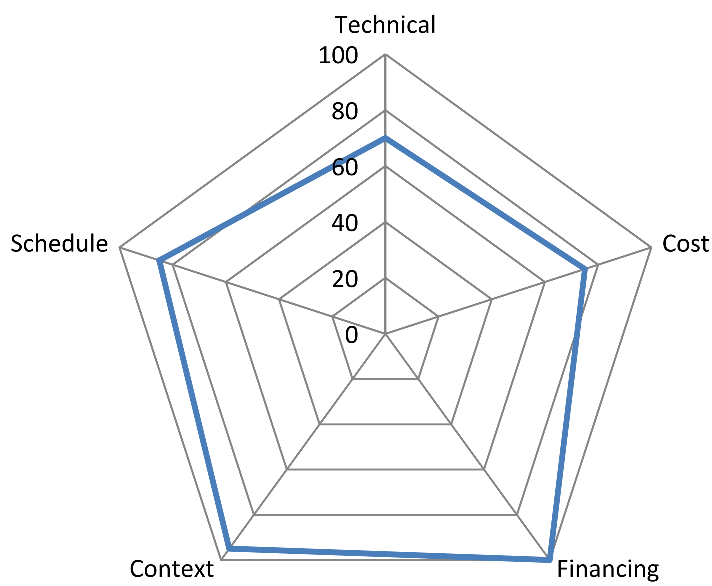

Figure A.2. *Detroit River International Crossing complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include selecting project arrangements on the basis of project outcomes and establishing public involvement plans.

DOYLE DRIVE

Project Overview

The Doyle Drive project is a unique project that forms one gateway to the Golden Gate Bridge in San Francisco, California. The 1.5-mi Doyle Drive corridor, also known as Presidio Parkway, was 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 intended to last 10 years was completed in 1995. The current project has eight contracts that will result in a new roadway, new structures including bridges and tunnels, and a depressed roadway section.

Project Complexity

The number of different financing sources being used for this project contributes to its complexity, as shown in Figure A.3. In addition, one of the contracts still in the planning phase is expected to be PPP.

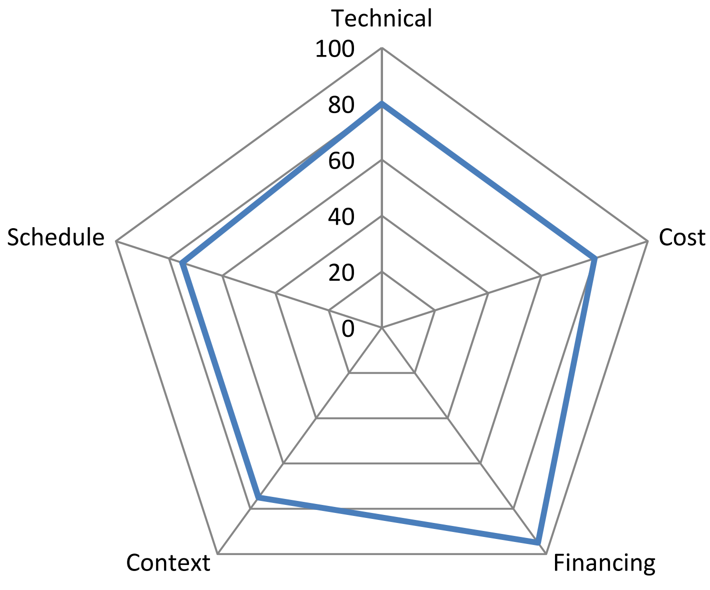

Figure A.3. *Doyle Drive complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include selecting project arrangements, which included multiple contracts; different project delivery methods; incentives to accelerate project delivery; value engineering; contractor-initiated changes and suggestions; and extensive, thorough monthly progress reports.

GREEN STREET

Project Overview

The Green Street project for the City of Saskatoon, Saskatchewan, Canada, consisted of recycling of asphalt and portland cement concrete rubble into high-value-added materials. The project focused on the 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 executed several field test sections to provide field validation of the structural designs.

Project 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 A.4 illustrates the complexity of this project.

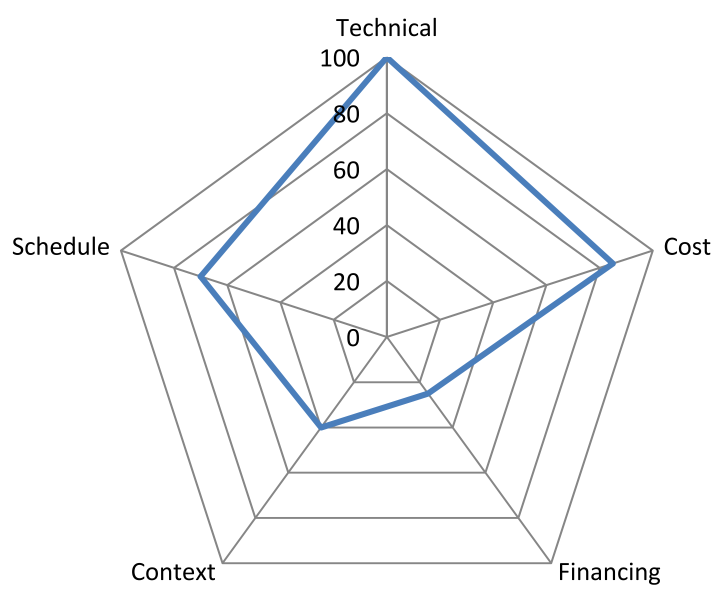

Figure A.4. *Green Street complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include establishment of flexible design criteria and selection of project arrangements on the basis of project outcomes.

HEATHROW INTERNATIONAL AIRPORT TERMINAL 5

Project Overview

The Heathrow International Airport Terminal 5 (T5) project in London includes constructing a new terminal building, a new air traffic control tower, ground traffic infrastructures (e.g., rail, underground, road, and guideways), and other auxiliary facilities (e.g., water tunnels). The planning phase of the project dates back to 1986, and the first phase of the project was completed in 2008. A second satellite building was still under construction and expected to be delivered by 2011.

Project Complexity

This project is one of the largest projects in Britain's engineering history and is the biggest construction site in Europe. Since project proposal approval in 1986, the planning and design phases of the T5 project have experienced turbulent changes (e.g., changes in technology, economic conditions, ownership, user requirements), creating significant management challenges for a project of this scale.

Furthermore, the total cost of the project is £4.3 billion ($6.7 billion), and numerous contractors, subcontractors, suppliers, subsuppliers, regulatory agencies, and other stakeholders are involved. The project is financed from a variety of revenue sources, with huge uncertainties. Figure A.5 depicts the complexity of this project.

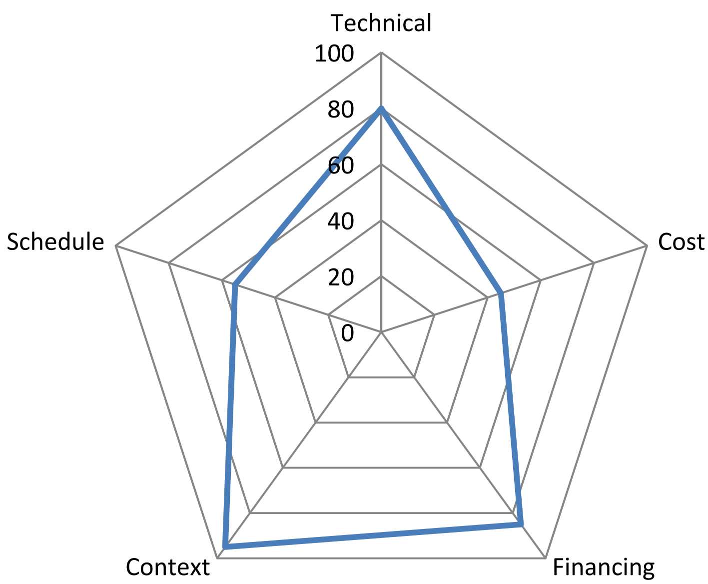

Figure A.5. *Heathrow T5 complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include performing comprehensive risk analysis, assembling project team, and defining project success by each dimension as required.

HUDSON-BERGEN LIGHT RAIL MINIMUM OPERABLE SEGMENT

Project Overview

The Hudson-Bergen Light Rail Transit System is a 20.3-mi-long light rail project that connects the densely populated Hudson River waterfront communities in New Jersey. The project also supports significant economic development that continues to take place in the region.

The transit system was built in three minimum operable segments (MOSs). MOS2, which was the subject of this case study, is a 6.1-mi-long system extending from Hoboken to the Tonnelle Avenue park-and-ride facility in North Bergen and an extension between 22nd Street and 34th Street in Bayonne.

MOS2 features a major tunnel (the 4,100-ft Weehawken tunnel) that includes the new Bergenline station at a depth of 160 ft from the surface.

The Hudson-Bergen Light Rail Transit System started as a traditional design–bid–build project. In 1994, it was determined that by using this traditional approach, the first operating segment would not be in service until 2005 because of funding constraints and other considerations.

Because of these concerns, New Jersey Transit decided to use the design–build–operate–maintain (DBOM) approach for project delivery. With this approach, it was possible to shave more than three years from the MOS1 duration.

For MOS2, New Jersey 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). As a result, the MOS2 DBOM contract was negotiated as a large change order to the MOS1 contract.

Project Complexity

Hudson-Bergen Light Rail is the first public transit project in the nation to use the DBOM construction methodology. To obtain the funds to make the project feasible, grant anticipation notes and several bonds were issued, given that a full funding grant agreement pays according to a multiyear schedule.

In addition, the project was constructed in populated and built-up areas, an environment that was challenging. Moreover, the length of the project contributed to the complexity in that the number of municipalities the project had to go through was significant compared to projects undertaken before. Figure A.6 shows the complexity of the Hudson-Bergen Light Rail project.

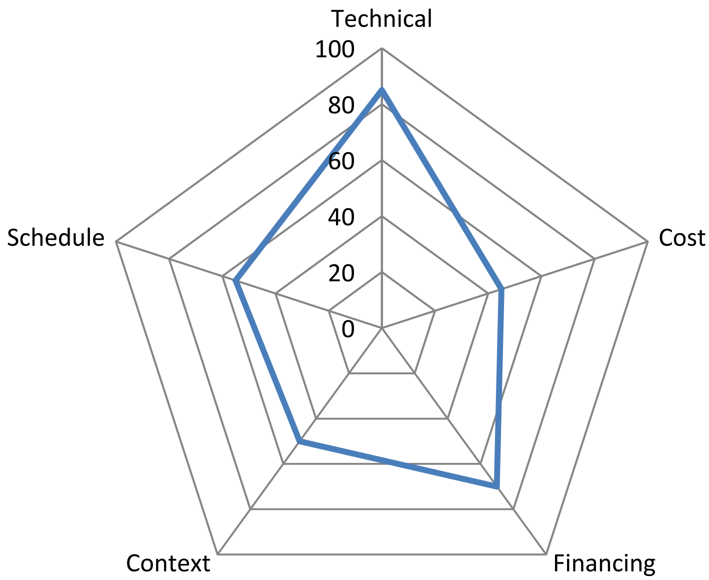

Figure A.6. *Hudson-Bergen Light Rail complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include selecting project arrangements on the basis of project outcomes, developing project action plans, determining involvement in right-of-way (ROW) and utilities, and establishing public involvement plans.

I-40 CROSSTOWN

Project Overview

The I-40 Crosstown project consists of the relocation of 4.5 mi of the I-40 Crosstown in Oklahoma City, Oklahoma, from approximately May Avenue to the I-35 interchange. This segment includes five major bridge structures. The project consists of 10 lanes designed to carry 173,000 vehicles per day at 70 mph. The case study project included 4.5 mi of new Interstate, ROW acquisition, agreements with the railroad, and 23 separate work packages in the construction phase.

Project Complexity

The I-40 Crosstown project was 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 stakeholder impact, which included relations with the railroad and ROW issues, added to the complexity of the project, as shown in Figure A.7.

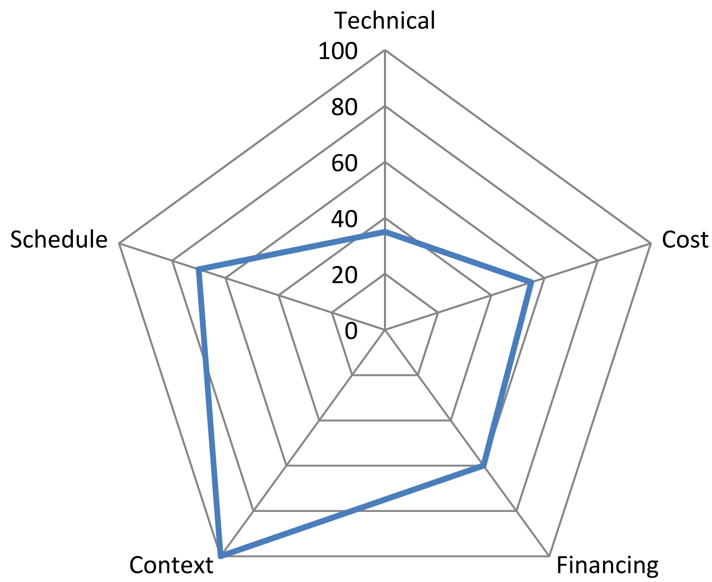

Figure A.7. *I-40 Crosstown complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include defining project success by each dimension as required, assembling project team, and establishing public involvement plans.

I-95 NEW HAVEN HARBOR CROSSING CORRIDOR IMPROVEMENT

Project Overview

The I-95 New Haven Harbor Crossing Corridor Improvement program, in New Haven, Connecticut, comprises seven completed and three current projects. The total program is estimated to cost $1.94 billion. This multimodal transportation improvement program features public transit enhancement and roadway improvements along 7.2 mi of I-95 between Exit 46 and Exit 54. The currently active projects include the following:

- Replacement of 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).

Project Complexity

The Pearl Harbor Memorial Bridge is the first extradosed bridge in the nation, which 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.

Receiving no bids required the owner to replan and repackage the project at great cost and delay. Furthermore, there are multiple packages in the program 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. Figure A.8 shows the complexity for this project.

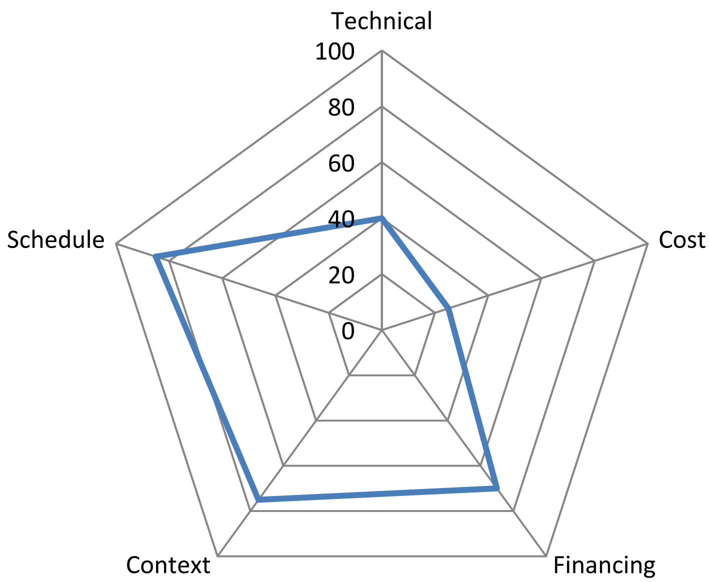

Figure A.8. *I-95 New Haven Harbor Crossing Corridor complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include performing comprehensive risk analysis, colocating team, and determining involvement in ROW and utilities.

I-595 CORRIDOR

Project Overview

The I-595 Corridor Roadway Improvements Project (Florida DOT I-595 Express) consists of the reconstruction of the I-595 mainline and all associated improvements to frontage roads and ramps from I-75 or Sawgrass Expressway interchange to the I-595 and I-95 interchange, for a total project length along I-595 of approximately 10.5 mi 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, being awarded the contract to serve as the concessionaire to use the design–build–finance–operate–maintain approach for the project for a 35-year term. This project delivery method 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 found that, if it could deliver the project using the design–build–finance–operate–maintain approach, it could reap considerable cost savings over the life of the project, as well as reach traffic capacity 15 years sooner than by using traditional methods.

The Florida DOT 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.

Project Complexity

The Florida DOT has been challenged to find the right level of oversight for the project. The process has been a learning experience for both the department and the concessionaire. It is very important to partner with local companies to learn the local culture and the processes of involved agencies on the part of the concessionaire. Figure A.9 shows the project complexity.

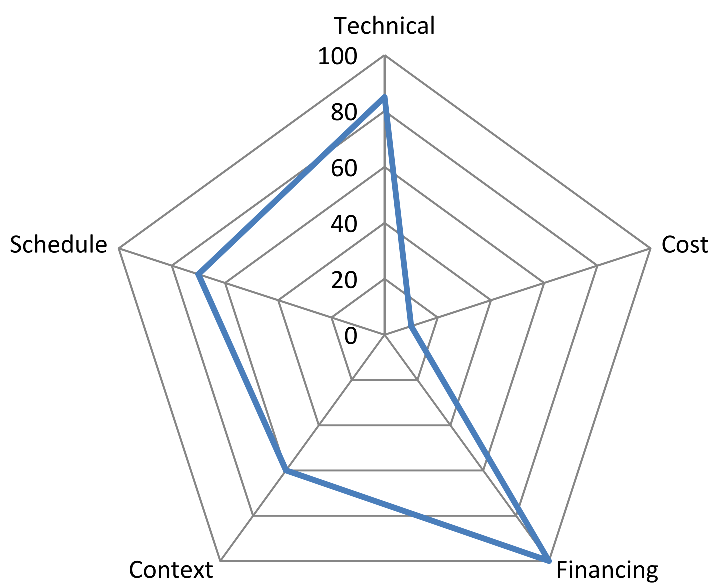

Figure A.9. *I-595 Corridor complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include assembling project team, preparing early cost model and finance plan, colocating team, evaluating flexible financing, and establishing public involvement plans.

INTERCOUNTY CONNECTOR

Project Overview

The InterCounty Connector project consists of 18 mi of construction on a new alignment and incorporates some reconstruction of interchanges and the 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 into five construction contracts and 47 environmental stewardship and mitigation contracts. The total anticipated cost is about $2.566 billion, with the environmental contracts accounting for $109 million.

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 of which have used DB procurement.

Each segment is scheduled to open incrementally; the currently contracted projects were expected to be finished in late 2011. The final two contracts are yet to be determined for letting periods and anticipated completion.

Nine interchanges, one intersection, two bridges, 4 mi of existing highway reconstruction, and 4.9 mi of resurfacing are slated to be completed during this project, along with the 18 mi of mainline construction.

The project is using multiple funding sources and will be part of Maryland's tolling network on completion. Grant anticipation revenue vehicle 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 loan are all sources of funding for this project.

Project Complexity

The use of the DB method and multiple separate contracts, as well as construction through an environmentally sensitive area, made this project complex, as shown in Figure A.10.

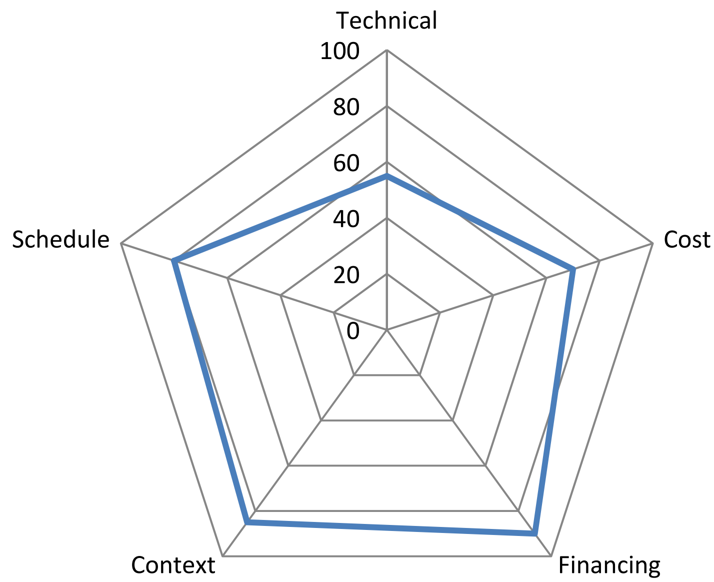

Figure A.10. *InterCounty Connector complexity diagram.*

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.

In this case study, there was a discrepancy between the complexity rank of each dimension and the score of the overall complexity for the dimensions, as shown in Table A.1.

TABLE A.1. INTERCOUNTY CONNECTOR COMPLEXITY RANK AND SCORE COMPARISON

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

Primary Methods and Tools

Primary methods and tools used for the project include preparing early cost model and finance plan, identifying critical permit issues, and evaluating flexible financing.

JAMES RIVER BRIDGE/I-95 RICHMOND

Project Overview

The project consists of the restoration of the 0.75-mi-long James River Bridge on I-95 through the central business district of Richmond, Virginia. The bridge's six lanes were originally designed and built in 1958 to carry one-third of the 110,000 vehicles per day that it was carrying when it was rebuilt in 2002.

The contractor proposed using preconstructed composite units that consisted of an 8.7-inch-thick 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 units. Crews finished the process by setting the new preconstructed unit in place overnight. The case study project includes the following:

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

Project Complexity

The project was regarded as complex because of construction scheduling restrictions resulting from location, volume of traffic, and potential impact on the public, as shown in Figure A.11. Project visibility was significant because of the immediate proximity to both the state legislature offices and the Virginia DOT central office. In addition, implementation of an untried construction method and an untried incentive and disincentive contract structure was complex.

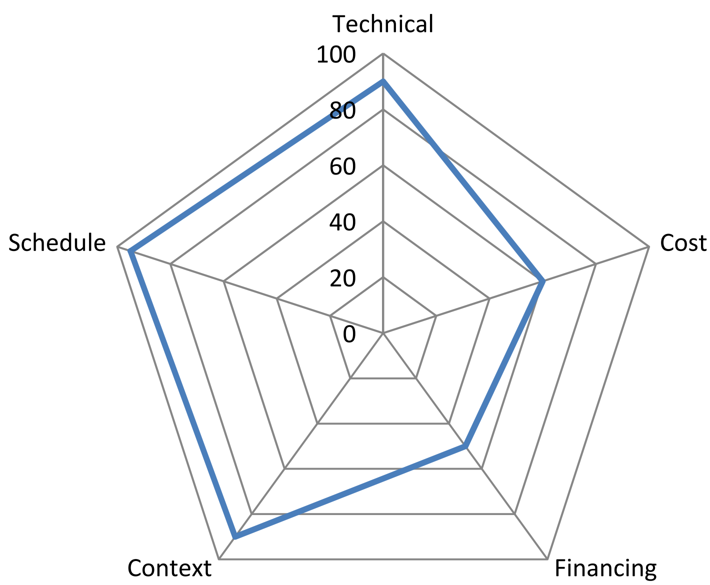

Figure A.11. *James River Bridge/I-95 Richmond complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include defining project success by each dimension as required, selecting project arrangements on the basis of project outcomes, and establishing flexible design criteria.

LEWIS AND CLARK BRIDGE

Project Overview

The Lewis and Clark Bridge spans the state line between Washington 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 ft long, with 34 spans carrying 21,000 vehicles per day. The bridge was built in 1929. 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.

Project Complexity

The Lewis and Clark Bridge is the only link between Washington and Oregon within at least a 1-hour distance. This factor greatly increased the context dimension complexity of the project. The owner had to seek solutions to minimize traffic impact.

User benefits were the major driver behind the decision to use a more-complex construction strategy (such as an incentive contract, which the owner had not used before), night and weekend full closure of the bridge, and precast deck replacement. Figure A.12 shows the project complexity.

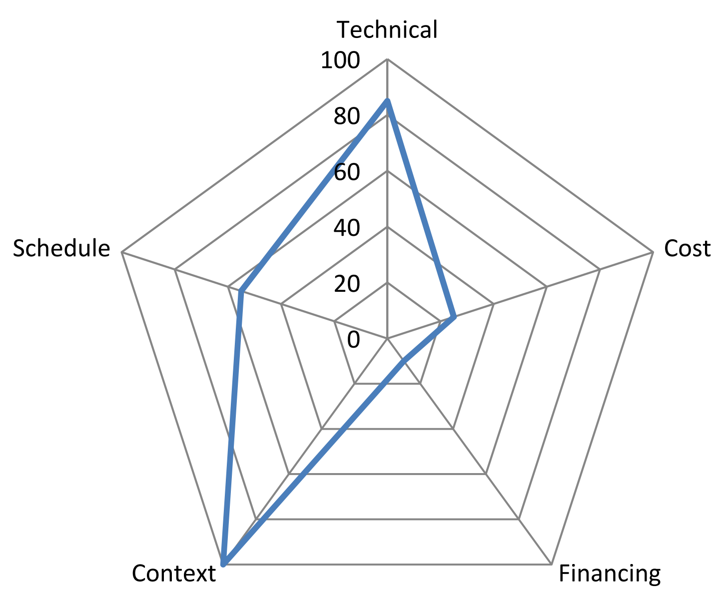

Figure A.12. *Lewis and Clark Bridge complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include defining project success by each dimension as required, selecting project arrangements on the basis of project outcomes, and establishing flexible design criteria.

LOUISVILLE–SOUTHERN INDIANA OHIO RIVER BRIDGE

Project Overview

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

Project Complexity

The project is regarded as complex because of the very large scope of work, insufficient funds, undefined financing plans, the presence of several historic districts and neighborhoods, multiple jurisdictions, political and environmental issues, and requirements for ongoing public involvement.

Design was virtually complete, but estimated construction costs ($4.1 billion) far exceeded available funds. Construction schedule, procurement, contracting, and so forth would depend on funding and financing plans that were under development (with recommendations due January 1, 2011). Figure A.13 shows the project complexity.

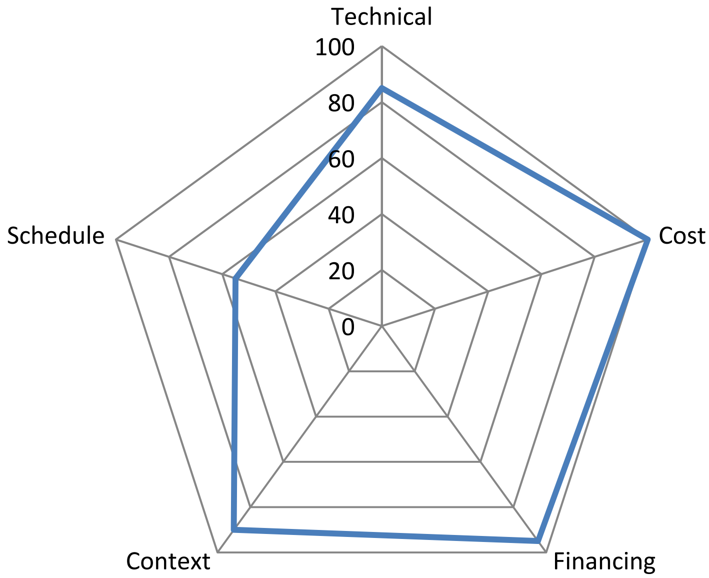

Figure A.13. *Louisville–Southern Indiana Ohio Bridge Crossing complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include determining involvement in ROW and utilities, determining work packages and sequencing, and establishing public involvement plans.

NEW MISSISSIPPI RIVER BRIDGE

Project Overview

The New Mississippi River Bridge project between St. Louis, Missouri, and East St. Louis, Illinois, is a complex project consisting of building a new, four-lane, long-span, cable-stayed bridge across the Mississippi River 1 mi 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, and I-70 Tri-Level Interchange and the main span and significant improvements at the I-55, I-64, and I-70 Tri-Level Interchange in East St. Louis, which will connect to I-70. The 1,500-ft main span will be the second-longest cable-stayed bridge in the United States upon completion.

Project Complexity

From the beginning, this project had several reasons to be considered a complex project, including time and cost constraints, technical complications, large scope, railroad and utility coordination, and special appropriation (use it or lose it) funding.

Crash incidence near the existing bridge was triple the national average, and the bridge ranks among the 10 worst corridors in the country in terms of congestion. Therefore, redesign and expansion of capacity were critical. Severe traffic (capacity, safety, and mobility) conditions also made the schedule a priority.

The original project plan had to be re-scoped into viable phases, given available funding, without sacrificing the overall project vision. The risk of cost and schedule overruns had to be mitigated to protect funding opportunities. Figure A.14 shows the project complexity.

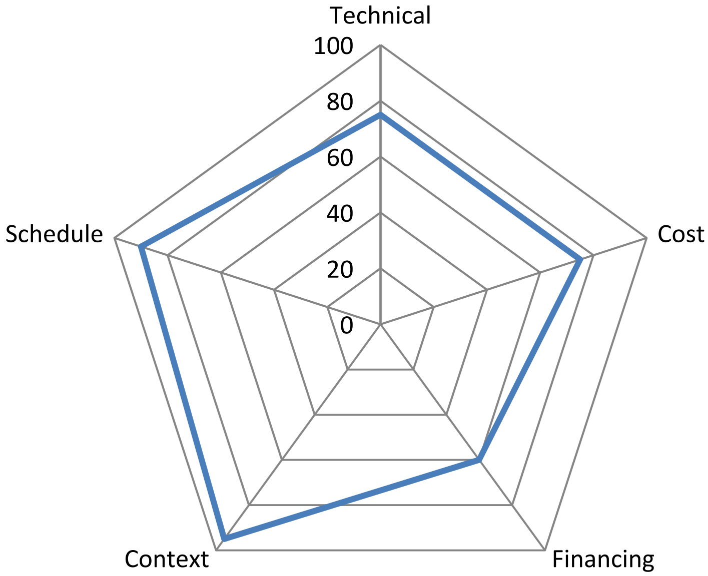

Figure A.14. *New Mississippi River Bridge complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include designing to budget, performing comprehensive risk analysis, and colocating team.

NORTH CAROLINA TOLLWAY

Project Overview

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 are the Triangle Parkway and the Western Wake Parkway, which compose the Triangle Expressway. These two projects combine for a total of approximately 19 mi 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 advertised initially in 2007, and completion is expected in 2011. The total awarded value of the project is approximately $583 million.

Project Complexity

This is the first tollway in North Carolina. Schedule and financing are keys to this project. It is important to get the project open to start collecting toll revenue. Figure A.15 shows the project complexity.

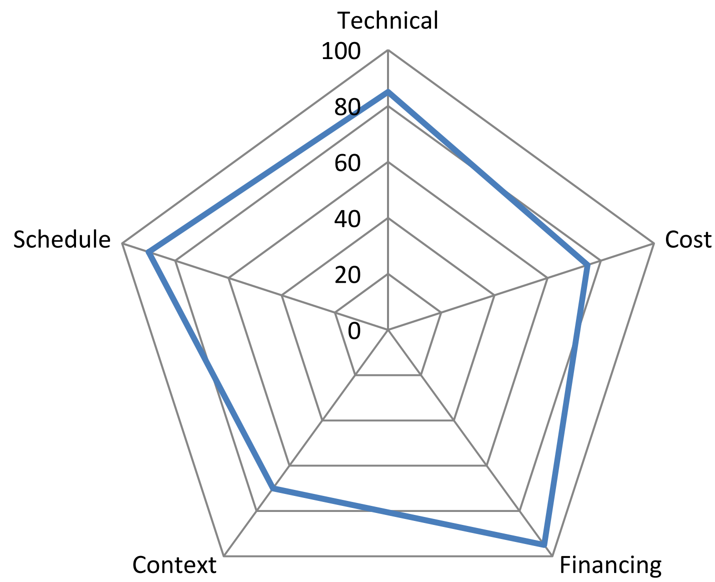

Figure A.15. *North Carolina Tollway complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include preparing early cost model and finance plan and establishing flexible design criteria.

NORTHERN GATEWAY TOLL ROAD

Project Overview

The Northern Gateway Toll Road was the first electronic toll road in New Zealand. This construction project was one of New Zealand's largest, most challenging, and most complex to date.

The project 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 was constructed to provide a straight and safe drive between Auckland and Northland. The project was delivered by the Northern Gateway Alliance (NGA), which comprised 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.

NGA was appointed by the New Zealand Transport Authority to deliver a major realignment and extension of the Northern Motorway approximately 30 km north of Auckland. This contract was the largest single contract to date ever awarded by the transport authority, which formed NGA in 2004 to design, manage, and construct the

State Highway One Northern Motorway extension. The project is being constructed through an area of very high environmental sensitivity and complex geology and topography.

Project Complexity

Funding was not in place at the start of the project, and environmental requirements insisted (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 to 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 of this money was pending and the risk of the project being halted was shared. Figure A.16 shows the project complexity.

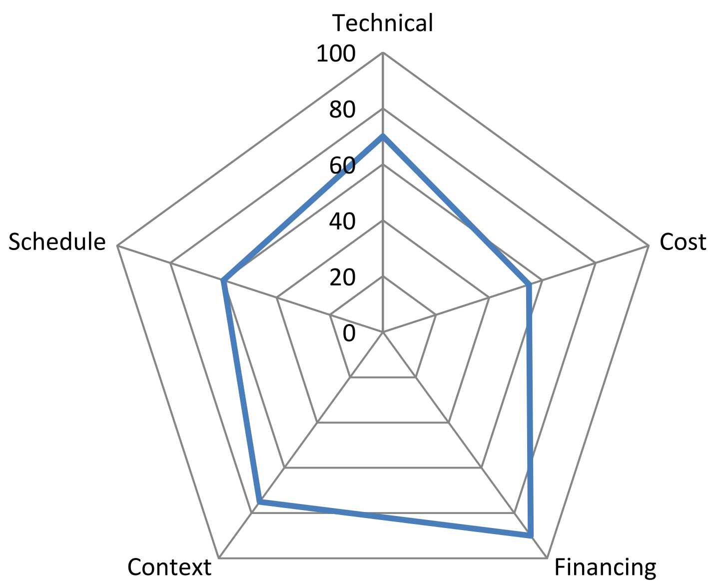

Figure A.16. *Northern Gateway Toll Road complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include defining project success by each dimension as required, selecting project arrangements on the basis of project outcomes, and establishing public involvement plans.

T-REX SOUTHEAST I-25 AND I-225

Project Overview

The Transportation Expansion (T-REX) project in Metro Denver, Colorado, consists of 17 mi 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 and I-225 interchange. The project also included 19 mi of light rail developments along those routes.

DB project delivery was selected because of its ability to reduce schedule and assign a single point of responsibility. The original cost for the project was $1.67 billion, which included the following costs:

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

Project Complexity

The project was considered complex because of the challenging work environment and the need to keep the highway open during construction, along with tracking of funding (highway versus traffic dollars) and the need to maintain bipartisan support, which created sensitive issues. Political parties did not want to lose elections because the T-REX project had failed. Figure A.17 shows the project complexity.

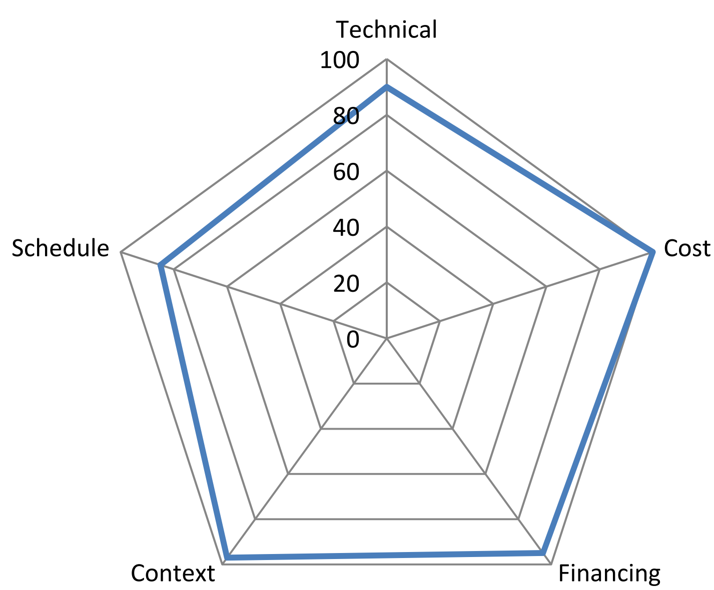

Figure A.17. *T-REX complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include selecting project arrangements on the basis of project outcomes, assembling project team, determining involvement in ROW and utilities, and establishing public involvement plans.

TEXAS STATE HIGHWAY 161

Project Overview

The Texas State Highway (TX SH) 161 project consists of construction of an 11.5-mi-long north–south tollway and frontage roads midway between Dallas and Fort Worth, Texas. The project will be built in phases with an overall construction cost of approximately $1 billion.

The southern terminus is at I-20 and runs north, with a full direct connector interchange with I-30, 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 subprojects.

Project Complexity

This project was complex because of its magnitude, multiple sources of financing, context (political influences), accelerated scheduling requirements, environmental concerns, and railroad involvement, as shown in Figure A.18.

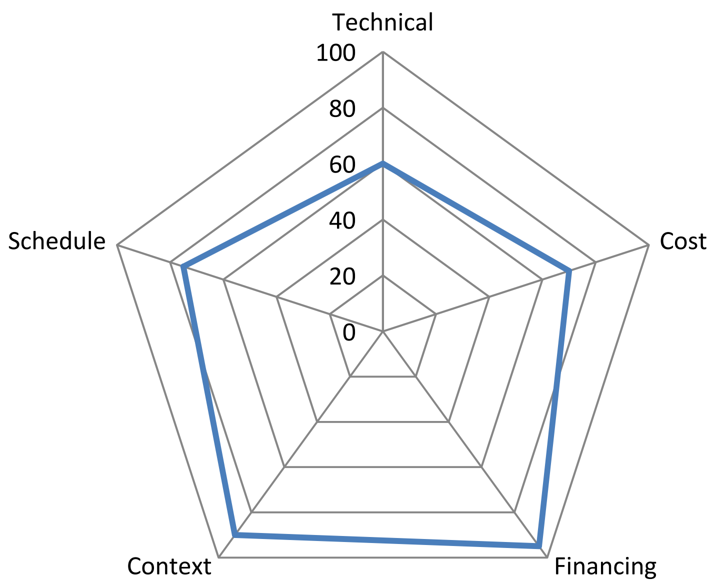

Figure A.18. *Texas State Highway 161 project complexity diagram.*

Primary Methods and Tools

Primary methods and tools used for the project include defining project success by each dimension as required, incentivizing critical project outcomes, and establishing public involvement plans.

B

PROJECT COMPLEXITY SURVEY, RANKING, AND SCORING

I. PROJECT INFORMATION

1. Project name and location:
2. Project scope of work:
3. Estimated project cost:
4. Project delivery method used on this project:

II. COST FACTORS

The following is a list of project cost factors that can contribute to complexity. Check the box following the factor indicating the importance of the factor in creating complexity on the project.

Cost Factors	Not a factor	Minor factor	Major factor	Remarks
Contingency usage	☐	☐	☐	
Risk analysis	☐	☐	☐	
Estimate formation	☐	☐	☐	
Owner resource cost allocation	☐	☐	☐	
Cost control	☐	☐	☐	
Optimization's impact on project cost	☐	☐	☐	
Incentive usage	☐	☐	☐	
Material cost issues	☐	☐	☐	
User costs/benefits	☐	☐	☐	
Payment restrictions	☐	☐	☐	

List any other sources of cost complexity not discussed above:

III. SCHEDULE FACTORS

The following is a list of project schedule factors that can contribute to complexity. Check the box following the factor indicating the importance of the factor in creating complexity on the project.

Schedule Factors	Not a Factor	Minor Factor	Major Factor	Remarks
Timeline requirements	☐	☐	☐	
Risk analysis	☐	☐	☐	
Milestones	☐	☐	☐	
Schedule control	☐	☐	☐	
Optimization's impact on project schedule	☐	☐	☐	
Resource availability	☐	☐	☐	
Scheduling system/software	☐	☐	☐	
Work breakdown structure	☐	☐	☐	
Earned-value analysis	☐	☐	☐	

List any other sources of schedule complexity not discussed above:

IV. TECHNICAL FACTORS

The following is a list of project technical factors that can contribute to complexity. Check the box following the factor indicating the importance of the factor in creating complexity on the project.

Technical Factors	Not a Factor	Minor Factor	Major Factor	Remarks
Scope of the project	☐	☐	☐	
Owner's internal structure	☐	☐	☐	
Prequalification of bidders	☐	☐	☐	
Warranties	☐	☐	☐	
Disputes	☐	☐	☐	
Delivery methods	☐	☐	☐	
Contract formation	☐	☐	☐	
Design method	☐	☐	☐	
Reviews/analysis	☐	☐	☐	
Existing conditions	☐	☐	☐	
Construction quality	☐	☐	☐	
Safety/health	☐	☐	☐	
Optimization impact construction quality	☐	☐	☐	
Typical climate	☐	☐	☐	
Technology usage	☐	☐	☐	

List any other sources of technical complexity not discussed above:

V. CONTEXT FACTORS

The following is a list of project context factors that can contribute to complexity. Check the box following the factor indicating the importance of the factor in creating complexity on the project.

Context Factors	Not a Factor	Minor Factor	Major Factor	Remarks
Public	☐	☐	☐	
Political	☐	☐	☐	
Owner	☐	☐	☐	
Jurisdictions	☐	☐	☐	
Designer(s)	☐	☐	☐	
Maintaining capacity	☐	☐	☐	
Work zone visualization	☐	☐	☐	
Intermodal	☐	☐	☐	
Social equity	☐	☐	☐	
Demographics	☐	☐	☐	
Public emergency services	☐	☐	☐	
Land use impact	☐	☐	☐	
Growth inducement	☐	☐	☐	
Land acquisition	☐	☐	☐	
Local economics	☐	☐	☐	
Marketing	☐	☐	☐	
Cultural impacts	☐	☐	☐	
Local workforce	☐	☐	☐	
Utility coordination	☐	☐	☐	
Railroad coordination	☐	☐	☐	
Resource availability	☐	☐	☐	
Sustainability goals	☐	☐	☐	
Environmental limitations	☐	☐	☐	
Procedural law	☐	☐	☐	
Local acceptance	☐	☐	☐	
Global/national economics	☐	☐	☐	
Global/national incidents	☐	☐	☐	
Unexpected weather	☐	☐	☐	
Force majeure events	☐	☐	☐	

List any other sources of context complexity not discussed above:

VI. FINANCING FACTORS

The following is a list of project financing factors that can contribute to complexity. Check the box following the factor indicating the importance of the factor in creating complexity on the project.

Financing Factors	Not a Factor	Minor Factor	Major Factor	Remarks
Legislative process	☐	☐	☐	
Uniformity restrictions	☐	☐	☐	
Transition to alternate financing sources	☐	☐	☐	
Project manager financial training	☐	☐	☐	
Federal funding	☐	☐	☐	
State funding	☐	☐	☐	
Bond funding	☐	☐	☐	
Borrowing against future funding	☐	☐	☐	
Advance construction	☐	☐	☐	
Revenue generation	☐	☐	☐	
Vehicle miles traveled fees	☐	☐	☐	
Cordon/congestion pricing	☐	☐	☐	
Monetization of existing assets	☐	☐	☐	
Franchising	☐	☐	☐	
Carbon credit sales	☐	☐	☐	
Public–private partnerships	☐	☐	☐	
Use of commodity-based hedging	☐	☐	☐	
Global participation	☐	☐	☐	
Risk analysis	☐	☐	☐	
Financial management software	☐	☐	☐	

List any other sources of financing complexity not discussed above:

VII. COMPLEXITY RANKING AND SCORING

1. Rank (1 to 5) the complexity of the following dimensions (cost, schedule, technical, context, and financing) with 5 being the most complex or most constrained and 1 being the least complex or least constrained. Do not assign equal values to any dimension (no tied rankings).

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. Indicate the overall complexity for each dimension by placing an X for each on the scale below.

	Scale				
Cost Dimension Complexity	Minimal		Average		High
	0	25	50	75	100

	Scale				
Schedule Dimension Complexity	Minimal		Average		High
	0	25	50	75	100

	Scale				
Technical Dimension Complexity	Minimal		Average		High
	0	25	50	75	100

	Scale				
Context Dimension Complexity	Minimal		Average		High
	0	25	50	75	100

	Scale				
Financing Dimension Complexity	Minimal		Average		High
	0	25	50	75	100

C PROJECT COMPLEXITY MAP (RADAR DIAGRAM)

Enter the scores from Section VII.2 of the complexity survey in Appendix B into a spreadsheet similar to the one in Figure C.1.

Dimension	Score (from VII.2)					
Technical						
Cost						
Financing						
Context						
Schedule						

Figure C.1. *Template for spreadsheet data format for project complexity map.*

After setting up the spreadsheet and entering the scores, create a visual representation of the project complexity in the form of a radar chart, as shown in Figure C.2. (In Excel, select the cells to map, click Insert in the menu bar, go to the drop-down pointer for Other Charts, and select Radar.) You want to generate a complexity map in the shape of a pentagon.

Dimension	Score (from VII.2)
Technical	70
Cost	90
Financing	50
Context	60
Schedule	80

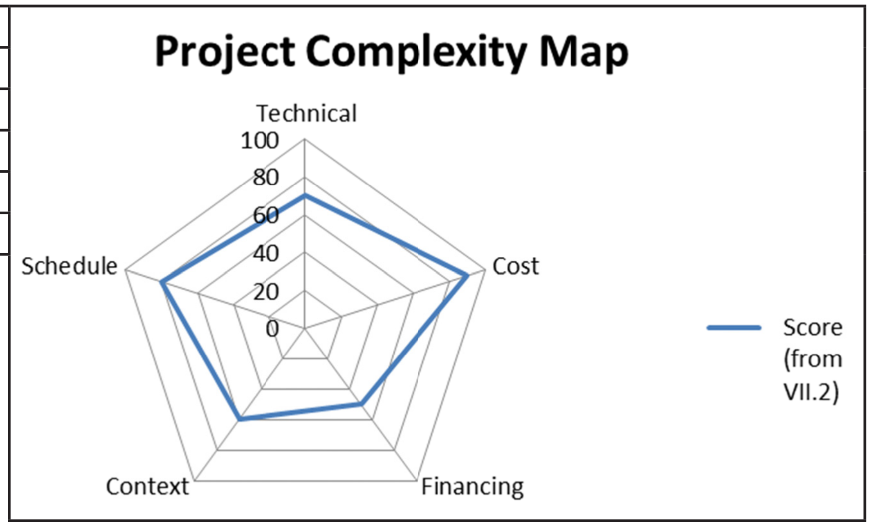

Figure C.2. *Sample project complexity spreadsheet and resulting complexity map (radar diagram).*

D

PROJECT COMPLEXITY FLOWCHART IN TABLE FORMAT

The complexity flowchart uses the table format shown in Table D.1.

TABLE D.1. SAMPLE TEMPLATE FOR PROJECT COMPLEXITY FLOWCHART

	Most Complex →				Least Complex
Dimension					
Complexity Factor					
Interactions					

1. List the project dimensions in rank order in the first row across, under the Most Complex → Least Complex headings, with the most-constrained dimension in the leftmost column and the least-constrained dimension in the rightmost column.
2. List the critical factors in the second row, along with notation on whether they are flexible or fixed or constrained.
3. Note the interactions in the third row of the table (such as interacts with schedule or interacts with schedule and technical).

The table can be added to in any number of ways when identifying or defining roadblocks and developing targeted project action plans using Method 5, as shown in Table D.2.

TABLE D.2. SAMPLE TEMPLATE FOR DEVELOPING PROJECT ACTION PLANS

	Most Complex →	→	→	→	Least Complex
Dimension					
Success factor					
Interactions					
Adequate resources?					
Can project succeed with typical systems (Y/N)?					
If No, a roadblock or speed bump exists					
Project action plan					

E

PROJECT MANAGEMENT TOOL SELECTION

After you have determined whether and how you will use each of the five 5DPM methods, check the appropriate tools (see below) to use with each method.

1. Define critical project success factors by each dimension as required.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team spent time before the start of design and construction identifying the critical success factors for the project.

2. Assemble the project team.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The team is the driver of the project. The project team has been given the authority needed to execute their responsibilities effectively to achieve the critical success factors.

3. Select project arrangements based on project outcomes.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   Once the project success factors were identified, the contracting method was selected to maximize the likelihood of achieving those critical success factors.

4. Prepare early cost model and finance plan.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   All members of the project team understood the financial model, including where the funding is coming from, limitations on funding availability, and project cash flows.

5. Develop project action plans.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   Legislators, community stakeholders, utilities, railroads, and many other individuals and groups may play a significant and influential role in a complex project, more so than on traditional projects. The project team discussed the political influence of various external groups and defined an action plan for positively directing this influence.

PROJECT MANAGEMENT TOOLS

1. Incentivize critical project outcomes.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   Members of the project team (including designers, builders, consultants, public relations, and so on) were incentivized to meet critical project goals. The incentives may range from traditional schedule, cost, and safety incentives to the performance areas from various external factors such as social, environmental, public involvement, and traffic mobility.

2. Develop dispute resolution plans.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team spent time developing a dispute resolution plan, including identification of high-impact dispute points such as those potentially arising from neighborhood groups, U.S. DOT Section 4(f) signatories, and other indirect stakeholders. The dispute resolution plan stipulates or addresses scope agreement issues and incorporates all local jurisdictions and signatory agencies.

3. Perform comprehensive risk analysis.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team implemented a formal risk analysis and mitigation process at early stages of the project. The risk analysis included clear and concise assignment of responsibilities and assignment of designated resources. The risk analysis included not only traditional cost and schedule issues but also context and financing issues, concerning the railroad, utilities, U.S. DOT Section 4(f), the National Environmental Policy Act, appropriations/capital bill allocation (use it or lose it funding), effect of delays, and related items. The result of the risk analysis was an aggressive mitigation plan, which was integrated with critical project success factors.

4. Identify critical permit issues.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team developed timelines for environmental, U.S. DOT Section 4(f), and other critical regulatory reviews, including flexible response mechanisms for permit issues and flexible planning and design for minimal impact where uncertainty is high (e.g., geotechnical and subsurface conditions, State Historic Preservation Office sites).

5. Evaluate applications of off-site fabrication.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team considered off-site fabrication for schedule control, quality control, minimal public disruption, noise control, loss of access, and minimization of environmental impact.

6. Determine involvement in ROW and utilities.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team determined the required involvement in ROW and utilities based on the project's critical success factors.

7. Determine work packages and sequencing.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team carefully designed work packages and construction sequencing to increase project success possibilities. Work packages and sequencing were determined based on consideration of available funding, available design resources, available contractor capabilities, and stakeholder concerns for project impact, including road-user costs.

8. Design to budget.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team designed the project within an established budget while considering stakeholder expectations to the extent possible.

9. Colocate team.

   _______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

   The project team was or is colocated, with each critical partner placing a dedicated, empowered representative to the project team in a common location.

10. Establish flexible design criteria.

_______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

The project team established flexible design criteria to meet the project cost, schedule, and quality performance requirements and critical permit issues. Flexible design criteria may be used to minimize potential ROW takes, utility conflicts, or U.S. DOT Section 4(f) issues. Flexible designs can be achieved by using the criteria of design exceptions, need-based reviews, performance specifications, mechanistic designs, innovative procurement mechanisms, or other similar methods.

11. Evaluate flexible financing.

_______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

The project team evaluated alternative funding sources including grant anticipation revenue vehicle (GARVEE) bonds, hybrid forms of contracting such as public–private partnerships, and project phasing to leverage financing.

12. Develop finance expenditure model.

_______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

The project team developed project cash flow projections and integrated them into project phasing plans for planned expenditures, including the use of resource-loaded project plans and network schedules to track expenditures and project cash needs.

13. Establish public involvement plans.

_______YES _______CONSIDERED BUT NOT USED _____ NOT CONSIDERED

The project team used extensive project outreach to address stakeholders' needs and concerns, including choice of design options and project delivery methods. Public involvement was solicited early in the planning phase, and a public communication plan was developed before the start of design and construction.

RELATED SHRP 2 RESEARCH

Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects (R03)
Performance Specifications for Rapid Highway Renewal (R07)
Guide for the Process of Managing Risk on Rapid Renewal Projects (R09)
Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process (R11)

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