REPORT S2-R10-RW-1

Project Management Strategies for Complex Projects

SHRP2 RENEWAL RESEARCH

SHRP 2
STRATEGIC HIGHWAY RESEARCH PROGRAM
Accelerating solutions for highway safety, renewal, reliability, and capacity

TRANSPORTATION RESEARCH BOARD
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The Second

STRATEGIC HIGHWAY RESEARCH PROGRAM

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Project Management Strategies for Complex Projects

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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.

SHRP 2 was authorized in August 2005 as part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The program is managed by the Transportation Research Board (TRB) on behalf of the National Research Council (NRC). SHRP 2 is conducted under a memorandum of understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the National Academy of Sciences, parent organization of TRB and NRC. The program provides for competitive, merit-based selection of research contractors; independent research project oversight; and dissemination of research results.

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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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FOREWORD

Jerry A. DiMaggio, D.GE, PE, *SHRP 2 Senior Program Officer, Renewal*

This research report, *Project Management Strategies for Complex Projects*, documents the research and results performed within SHRP 2 project R10. The research scope involved the development of surveys, case study reports, training, technical tools, and a guide to address the current-day challenges of infrastructure project management that are considerably more complex than traditional projects. The R10 project reports 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, or renewing existing facilities. The project management issues involved with infrastructure renewal are different from the issues for new construction. Correspondingly, new project management approaches must be integrated into mainstream practice 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 approach for project management of complex projects is not a new subject. However, it is extensively developed, outlined, and clearly mapped for acceptance and integration within the R10 project. The five dimensions are cost, schedule, technical, context, and finance. Successful use of the approach involves five methods which are unique for each project:

- Define project success factors by each dimension, as required;
- Assemble project team;
- Select project arrangements;
- Prepare early cost model and finance plan; and
- 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 agency existing program and project management policies and procedures through demonstration projects, training, and change-management assistance.

CONTENTS

Executive Summary

Successful management of complex transportation projects requires a fundamental change in how projects are planned, developed, designed, procured, and constructed. SHRP 2 Renewal Project R10, Project Management Strategies for Complex Projects, investigated strategies, tools, techniques, and methods that can be used effectively for complex-project management.

This report begins with a discussion of the transition currently under way in the practice of project management, which is becoming more holistic. Traditional project management has focused on cost, schedule, and technical factors. However, complex projects, as defined for this research, require the transportation agency to manage broader contextual factors and apply innovative financing techniques. This progression leads to the development of a new five-dimensional project management (5DPM) approach.

The goal of the 5DPM approach is to identify issues that should be planned for and managed proactively, rather than retroactively as in the traditional approach. The five areas of this new project management approach are outlined in Table ES.1.

The 5DPM approach is supported by the British conceptual framework and synthesizing field study *Rethinking Project Management* (Winter and Smith 2006). Winter and Smith introduced five new directions of thought for restructuring project management: (1) accounting for external factors instead of perceiving them as risks, (2) changing management from a linear process to an interactive process, (3) emphasizing project completion in terms of creating value, instead of focusing on an end product, (4) thinking of the project on a broad spectrum with multiple purposes and no set predefinition in lieu of a defined start and end point with strict guidelines, and (5) focusing on the training of managers to rely on experience and intuition instead of merely following detailed procedures.

The first step in the process of analyzing project management strategies for complex projects was to break down the five-dimensional model into appropriate categories and factors. Chapter 2 shows how the factors are grouped into categories to identify overarching issues within each dimension. The main purpose of Chapter 2 is to provide definitions and summaries of the types of requirements that may arise throughout a transportation project. Those descriptions remain constant throughout the course of the R10 project for consistency.

Although Chapter 3 summarizes the literature review, the detailed results of the review are provided in Appendix A, which includes a literature table for each dimension of complexity. Each table includes the literature references and shows the factors discussed in each study. The purpose of the literature tables was to identify the factors that have been researched previously and those that have been underrepresented in previous research. The factors are organized within each appropriate dimension and category, so the factors that relate to one another are structured together. These tables assisted with the analysis portions of this project.

Chapter 3's analysis of the literature review identifies issues related to the review-defined factors that need to be managed in complex projects. That chapter is organized according to the five

Table ES.1. The Five Dimensions of Complexity with the New Project Management Approach

Dimension	Description
Cost	Involves quantifying scope of work in dollars
Schedule	Relates to calendar-driven aspects of the project
Technical	Includes all typical engineering requirements
Context	Encompasses external influences that affect project development and progress
Financing	Relates to the influence of how the project is funded on the final scope of work

dimensions. Each dimension's section describes the issues found through research studies that the transportation agency needs to account for to manage complex projects effectively. A wide variety of issues was found, each of which has the potential to affect the planning and implementation of a construction project. Many of the issues span multiple factors, and many also pertain to other dimensions. For the sake of simplicity, the identified issues are broken down into the most-applicable factors.

This report then details the development of the case studies, methods, and tools as well as the guide and workshop-based training materials for complex-project management. More detailed information for each of the case studies from this project can be found in the R10 case study report (www.trb.org/Main/Blurbs/167481.aspx). A summary of each case study is provided in a guide appendix, available at www.trb.org/Main/Blurbs/167482.aspx. Chapters 4 and 5 of this report provide an overview of the case studies and details on how the methods and tools were identified.

This information was then enhanced to develop a guide for managing complex projects, as covered in Chapter 6. The information was also used to develop training materials. Chapter 7 presents information on pilot training sessions, and Chapter 8 describes additional workshops that were used to develop the guide and training materials.

The guide was developed to facilitate the use of effective strategies in managing complex projects. To help improve the state of the practice, the guide focuses on practical methods and tools and techniques that were designed to be immediately beneficial to transportation professionals. The focus is on complexity mapping, five methods, and 13 tools (Figure ES.1). The training also focuses on these items, with a presentation of complexity mapping and the five methods.

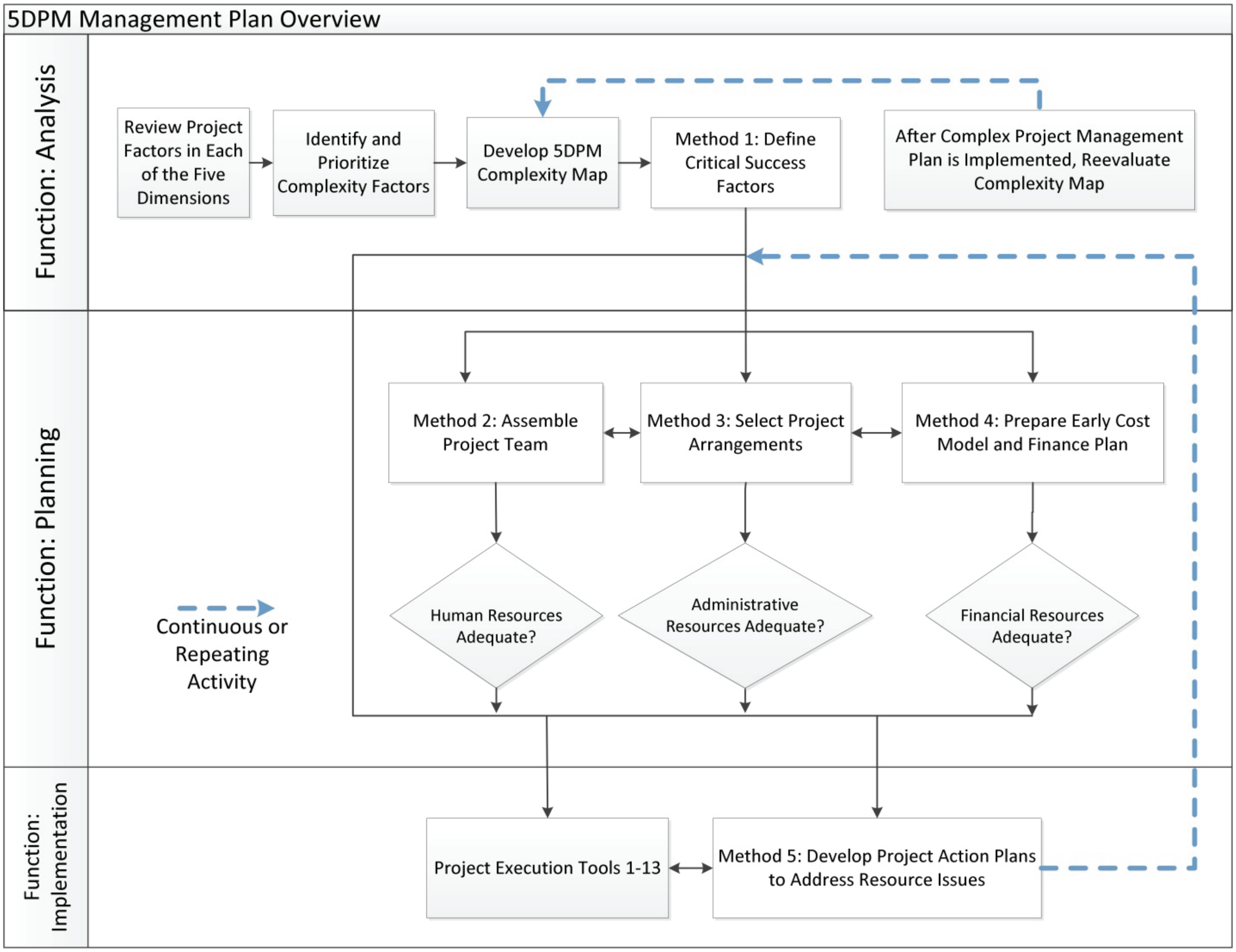


Figure ES.1. Guide and training outline.

CHAPTER 1

Introduction

The definition of successful transportation project management is expanding to include broad, holistic, and long-lived measures of project performance (Jugdev and Muller 2005). Jacobs Engineering Group et al. (2009) posited a three-part definition of successful project management as follows:

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

As part of the redefinition of project success, the roles and responsibilities of project managers are expanding beyond the traditional cost-budget-quality triangle (Atkinson 1999) to include management of relational, cultural, and stakeholder issues (Cleland and Ireland 2002). In the midst of this evolution, the definition of project management has become blurred, and consensus on effective practices is lacking.

For example, one book describes project management as the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements (Gray and Larson 2008). Another text takes a more specific approach: project management is the planning, organizing, directing, and controlling of company resources for the relatively short-term objective that has been established to complete specific goals and objectives. Furthermore, project management uses the systems approach to management by having functional personnel assigned to a specific project (Kerzner 2006).

Other contemporary project management concepts focus on the identification and management of risk (Touran 2006), while others emphasize sustainability (Shen et al. 2007) and life-cycle conceptual estimating skills (Jaafari and Manivong 2000) among other issues.

The weight of evidence suggests a broad recognition that the nature of project management is changing, but little agreement over how it is changing. In response to this situation, a research team at the University of Manchester, United Kingdom (UK), developed an excellent conceptual framework and synthesized field study of the changing nature of project management in 2003 entitled *Rethinking Project Management* (Winter and Smith 2006).

The project brought together industry, government, and academic experts on the management of complex projects. The study aimed to identify the needs for project management research and to update the current practice by identifying the evolution of fundamental project management theories. The researchers applied a rigorous approach to this problem and developed a framework for five new directions of thought to define the differences between routine project management and the management of complex projects in the 21st century (Table 1.1).

The five new directions in the framework evolve from robust logic and have important applicability to SHRP 2 Renewal Project R10.

Direction 1 entails the shift from a life-cycle theory of projects and project management to a complexity theory. Essentially, this change entails recognizing that projects are influenced by external agents in addition to technical engineering and construction means and methods. The authors advocate developing multiple theories to account for multiple external influences, in contrast to traditional methods that treat external influences as risks. Following directly from the move to the complexity theory, Direction 2 entails a change from conceptualizing projects as a series of static, linear, and discrete events toward recognition of the interactive, interpersonal, and dynamic nature of modern projects.

In the same vein, the theory points out the need to refocus on value creation rather than project creation, which is a shift that forms the third direction. Direction 3 is a paradigm shift to treat projects as end states that have a purpose in society rather than as an assembly of well-engineered and manufactured parts.

Table 1.1. Five New Directions of Thought in Project Management (after Winter and Smith 2006)

Theory ABOUT Practice	
Direction 1	**Life-Cycle Theory *OF* Projects and PM ⇨ ⇨ Complexity Theories *OF* Projects and PM**
From:	The life-cycle model as *the* single theory of projects (e.g., "all projects comprise a series of defined tasks organized in a life cycle of stages"), which is often portrayed as the actual reality of projects, and the (often unexamined) assumption that the life-cycle model *is* (assumed to be) the actual "terrain" (i.e., the actual reality "out there" in the world).
Toward:	Multiple theories that seek to understand the complexity of projects (e.g., the social process and the flux of events, social interaction, stakeholder relations, and individual human action) and new models and theories that are explicitly presented as only *partial* theories of the complex "terrain."
Theory FOR Practice	
Direction 2	**Projects as Instrumental Processes ⇨ ⇨ Projects as Social Processes**
From:	The instrumental life-cycle image of projects as a linear sequence of tasks to be performed on an objective entity "out there," by using codified knowledge, procedures, and techniques, and that is based on an image of projects as temporary apolitical production processes.
Toward:	Concepts and images that focus on social interaction among people, illuminating the flux of events and human action, and the framing of projects (and the profession) within an array of social agenda, practices, stakeholder relations, politics, and power.
Direction 3	**Product Creation ⇨ ⇨ Value Creation**
From:	A focus on product creation—e.g., the development or improvement of a physical product, system or facility—and monitored and controlled against specification (quality), cost, and time.
Toward:	A focus on value creation as the primary focus of projects, programs, and portfolios. "Value" is seen as having multiple meanings linked to different purposes: organizational and individual.
Direction 4	**Narrow Conceptualization ⇨ ⇨ Broad Conceptualization**
From:	The narrow conceptualization of projects as temporary production systems, starting from an objective or goal "given" at the start and named and framed around single disciplines (e.g., information technology projects).
Toward:	The broader conceptualization of projects and programs as being multidisciplinary, having multiple purposes, not predefined, permeable, contested, and open to renegotiation throughout.
Theory IN Practice	
Direction 5	**Trained Technicians ⇨ ⇨ Reflective Practitioners**
From:	Trained technicians who follow detailed procedures and prescriptive techniques based on mainstream project management theory (the "from" parts of Directions 1–4).
Toward:	Reflective practitioners who can operate effectively in complex project environments through experience, intuition, and the pragmatic application of theory.

The fourth direction entails a trend toward integrated, multidisciplinary structures with hybrid forms of governance.

Finally, the theory seeks to shift the practice from training project managers to use various analytical tools to inspiring project managers to be thoughtful, resourceful, and pragmatic in applying their education and experience in managing complex projects. This is the fifth direction of thought, which best underscores the ultimate objective of the SHRP 2 R10 project.

Winter and Smith (2006) ultimately posed two questions that directed the SHRP 2 approach for the R10 project. The questions develop a direct link between the researchers and the practitioners that benefits both parties as well as society:

- How can scholarly projects that engage pressing questions relating to the management of projects enhance the empirical breadth and theoretical sophistication of our work?
- How may "engaged scholarship" transform aspects of the management of projects in practice?

To begin to answer these questions, the present research process started with what is known and accepted about the current practice of project management.

Traditional project management involves integrating three dimensions of a project that must be satisfied to deliver the required scope of work (Jacobs Engineering Group et al. 2009). These are the technical, schedule, and cost dimensions (Figure 1.1).

The traditional approach to project management has generally served the industry well during the expansion of the U.S. transportation infrastructure. However, this infrastructure is getting old, with much of the highway system having exceeded its original design life and no longer functioning at the capacity for which it was designed (ASCE 2009).

This situation has created a need to address the aging infrastructure problem, and the need is extremely urgent, as illustrated by catastrophic failures and closures in states from coast to coast (Minnesota DOT 2008, ASCE 2009). As a result,

Figure 1.1. Traditional project management.

a shift from building new infrastructure to replacing, expanding, or renewing existing infrastructure has occurred.

The project management issues involved with infrastructure renewal are markedly different from those for new construction. This is a fact that furthers the need for a change in project management approaches for the nation's infrastructure. Not only are infrastructure renewal projects inherently more complicated, but also the situation has been exacerbated by years of underfunded maintenance and replacement. In other words, what would have been a complex process under ideal circumstances has been made even more challenging because of the need for rapid renewal to avert infrastructure failures. In addition, the 1990s brought demand from public owners to deliver public infrastructure projects faster and with more control over time and cost (Gransberg et al. 2006, Lopez del Puerto et al. 2008, Sillars 2009).

A typical example of the complexity of rapid renewal projects is I-405 in Portland, Oregon. This highway's concrete pavement is more than 40 years old. It carries 125,000 cars per day and has been literally 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 also it needs 26 bridges and overpasses to be raised to meet current Federal Highway Administration (FHWA) clearance requirements. Raising these structures on I-405 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 be raised, literally, to nearly the second floor of a building that fronts it.

The situation is further complicated by the need to lower, relocate, or both, an unusually large number of utilities that crisscross the project limits (Oregon DOT 2009). 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.

The problem with traditional project management cost and schedule control is particularly acute in large, complex projects, as noted in the final report of the National Cooperative Highway Research Program (NCHRP) Project 20-69 (Jacobs Engineering Group et al. 2009). Results from this research indicate that of projects with more than $5 million in construction costs, less than 20% were on or under budget, and only 35% were delivered on time.

The final report from that NCHRP project further identified a number of factors that contribute to cost and schedule issues, including difficulty in obtaining the rights-of-way, utility conflicts, underground conditions, environmental and political issues, design problems, lack of accountability, inadequate protocols, and lack of coordination between project development phases. The report concluded that most of these issues can be mitigated by using effective project management protocols and procedures, specifically early and consistent coordination between departments and agencies responsible for these project tasks from the beginning of the project.

The report demonstrates the need to train project managers to think of the project as an entire integrated system, in addition to managing each of the individual phases. However, managing complex systems has not traditionally been a centerpiece of educational programs, professional development, industry practice, or agency structures. This has led to calls for a special class of project managers who are specifically trained through new standards, training programs, and certification processes to manage complex projects (Whitty and Maylor 2009).

Undergraduate and graduate curricula, agency structures, and continuing education requirements for licensure and registration impose large forces against changing the nature of project management to better address the needs of complex projects. A much more accessible solution to increasing capacity for complexity involves introducing alternative project delivery methods that could satisfy many of the increased project requirements through changes in procurement and contracting. Although effective for improving project performance (FHWA 2006, Thomas et al. 2006), alternative project delivery did not specifically address required changes in project management skill sets, which represent a continuing challenge to constant performance enhancements for complex projects (Leicester 2009).

In fact, it could be argued that alternative project delivery systems and innovative contracts represent a more advanced toolkit for managing complex projects. However, without appropriately trained project managers, such contractual and administrative changes represent an added layer of complexity to the project management equation.

Project quality has become the prime variable of interest that needs to be guaranteed as public owners accelerate the work pace (Gransberg and Molenaar 2004, Gransberg and Windel 2008, Gransberg et al. 2008).

The shift to alternative project delivery also shifted emphasis from minimizing costs to controlling costs as projects became larger and more complex and the time frame allotted for detailed design became shorter. A recent Oklahoma Turnpike Authority study of the relationship between design costs and construction cost growth showed that the agency had more control of final construction costs when it allotted more time and resources to complete the design (Gransberg et al. 2007).

Furthermore, infrastructure renewal projects are prone to much more contextual complexity than are new construction projects because of the presence of existing utilities (Chou et al. 2007, Anderson et al. 2009); the need to interface multimodal transportation systems (Touran et al. 2009); the increased political, social, and regulatory demands (Handy et al. 2002, Little 2006); and the frequent need to maintain traffic safety and mobility in work zones (Scriba and Seplow 2006, Anderson et al. 2009).

Last, 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 have added new modes of complexity to projects (Tetlow 2004, Gallay 2006).

As a result, managers of complex projects, both large and small, must ultimately optimize the available resources (time and money) with the technical performance needs of the project (design) while operating under both known and unknown constraints (context) and accommodating the requirements of new financing partners and funding models (financing). Thus, complex-project management involves an increase in the project manager's skill set from the traditional three dimensions to five dimensions, as depicted in Figure 1.2. Generally speaking, this kind of management requires the owner to think continuously about risk, and this thinking includes a focus on budgeting, scheduling, designing, allocating, and pricing.

Complex-project management tools must reach beyond merely adding arbitrary risk contingencies in budgets or

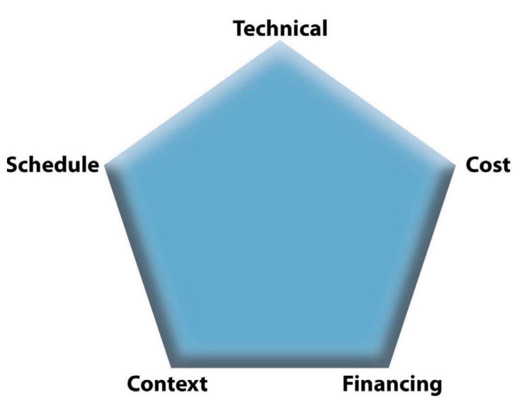


Figure 1.2. Complex-project management.

risk-shedding clauses in contracts and must furnish agencies with the abilities to both quantify the potential impact of risk and assist them in determining the most appropriate means to allocate risk among themselves and the industry parties.

For example, the Federal Transit Administration (FTA) mandates that transit agencies conduct a formal risk analysis to obtain federal funding for a project (FTA 2003). For the past two decades, international public transportation agencies have been conducting these kinds of analyses routinely on projects such as the Chunnel between the United Kingdom and France and public–private partnership projects for roads, bridges, and rails in Europe as well as in Australia and New Zealand (Australian Department of Finance and Administration 2006). The Ontario Ministry of Transportation developed an extensive tool to manage the risks on the E407 motorway project in Toronto, as did the San Diego Airport in California for its complex terminal. The California Department of Transportation (Caltrans) also recognized the need to formally share risk in a recent project delivery manual (Trauner Consulting Services 2007).

Building on the foundation laid by the UK initiative on new directions in project management, agencies can organize current project management knowledge in a supplementary framework that combines the three traditional project management knowledge areas (cost, schedule, and technical) with two additional dimensions that are often present in complex projects: context and financing.

In keeping with Direction 1 toward applying theories of complexity to model project management, the emerging model recognizes that the traditional project management approaches to cost, schedule, and design will be more challenging because they must now be viewed as part of a social, dynamic, and broadly conceptualized process.

Adding an expanded, more-complex understanding of cost, schedule, and design to the new project management factors of context and financing creates a framework organized around the five critical dimensions of complex-project management (hereafter referred to as 5DPM). Thus, complex projects can be differentiated by the requirement to actively manage in more than the three dimensions of traditional project management. Although very broad and conceptual in nature, the five new directions of thought for restructuring project management (Winter and Smith 2006) were extremely helpful for developing an applied model of complex-project management.

Direction 1 suggests the need to account for external project factors instead of perceiving them as risks. This direction indicates clearly that context matters and that project managers can no longer think of external factors as issues beyond their control that have a negative impact on the internal factors of cost, schedule, and technical quality. The managers of complex projects must identify and account for external contextual factors very early in the project life cycle.

Direction 2 argues that project managers must view projects as interactive processes rather than linear functions. This change clearly has impacts on cost, schedule, and technical issues, indicating that project managers of complex projects must continually update schedules, costs and budgets, and design as interactive, interdependent processes. Given that the source of financing will increasingly dictate cost, schedule, and technical parameters, Direction 2 presents a fundamental change for the practice of project management.

Direction 3 emphasizes the need for project managers to view project scheduling in terms of creating value instead of a contractually defined start-and-end period. Direction 3 obviously has implications for how managers of complex projects consider scheduling decisions on project delivery, procurement, integrated supply chains, use of prefabrication, and so forth. Each of these schedule decisions will interactively have an impact on cost and technical decisions, as suggested in Direction 2. Likewise, financing and context issues may have an impact on scheduling decisions.

Direction 4 encourages project managers to think of the project from multiple viewpoints with multiple purposes and with no set, predefined project parameters. This direction encourages innovation, hybrid contracting, and relational partnering, in lieu of mandating defined start and end points for each phase, using strict guidelines for project decisions, and relying on standards instead of good engineering judgment.

Direction 5 encourages project managers to rely on experience and intuition instead of detailed procedures. This direction has an impact on how managers of complex projects consider cost, schedule, and technical issues, including their reliance on historical data, industry and agency standards, and so on. In other words, each complex project should be analyzed independently with a custom set of performance goals uninhibited by history or conformity within the industry. This frees project managers of complex projects to change cost, schedule, and technical parameters in response to unique contextual factors or to demands of innovative financing systems.

The sources of complexity and the literature review described in the following chapters are organized by the five dimensions of project management as follows:

- Cost: Involves quantifying the scope of work in dollar terms:
  - Risk
  - Preliminary program
  - Planning and construction
  - Issues
- Schedule: Relates to the calendar-driven aspects of the project:
  - Time
  - Risk
  - Planning and construction
  - Technology
  - Mathematical modeling
- Technical: Includes all of the typical engineering requirements:
  - Scope
  - Internal structure
  - Contract
  - Design
  - Construction
  - Technology
- Context: Encompasses the external influences that have an impact on project development and progress:
  - Stakeholders
  - Project-specific factors
  - Local issues
  - Resource availability
  - Environmental issues
  - Legal and legislative requirements
  - Global and national influences
  - Unusual conditions
- Financing: Relates to the need for understanding how the project is being paid for:
  - Process
  - Public relations and support
  - Revenue stream
  - Asset value
  - Project delivery methods
  - Risk

Figures 1.3 and 1.4 illustrate the interconnectivity of the various dimensions and provide the information targets that must be met to accomplish the research objectives of the SHRP 2 R10 study of managing complex projects.

Figure 1.3 is a generalized figure for how the 5DPM framework is interwoven through the entire project life cycle and Figure 1.4 provides a detailed portion of Figure 1.3 that focuses on the areas specific to project execution. A quick glance at these figures demonstrates the complexity of adding two dimensions to the current three-dimensional project management process.

The first step in synthesizing the information gathered during the literature review was to identify common success factors and universal effective practices that can be applied to virtually all projects. The second step was to categorize those success factors and effective practices for each of the five dimensions. Identifying effective practices for managing these complexity factors is confirmed, ideally, by comparing project or agency attributes where a similar strategy was used but where the strategy led to success in one case and not in the other. Such comparisons allow researchers to investigate the

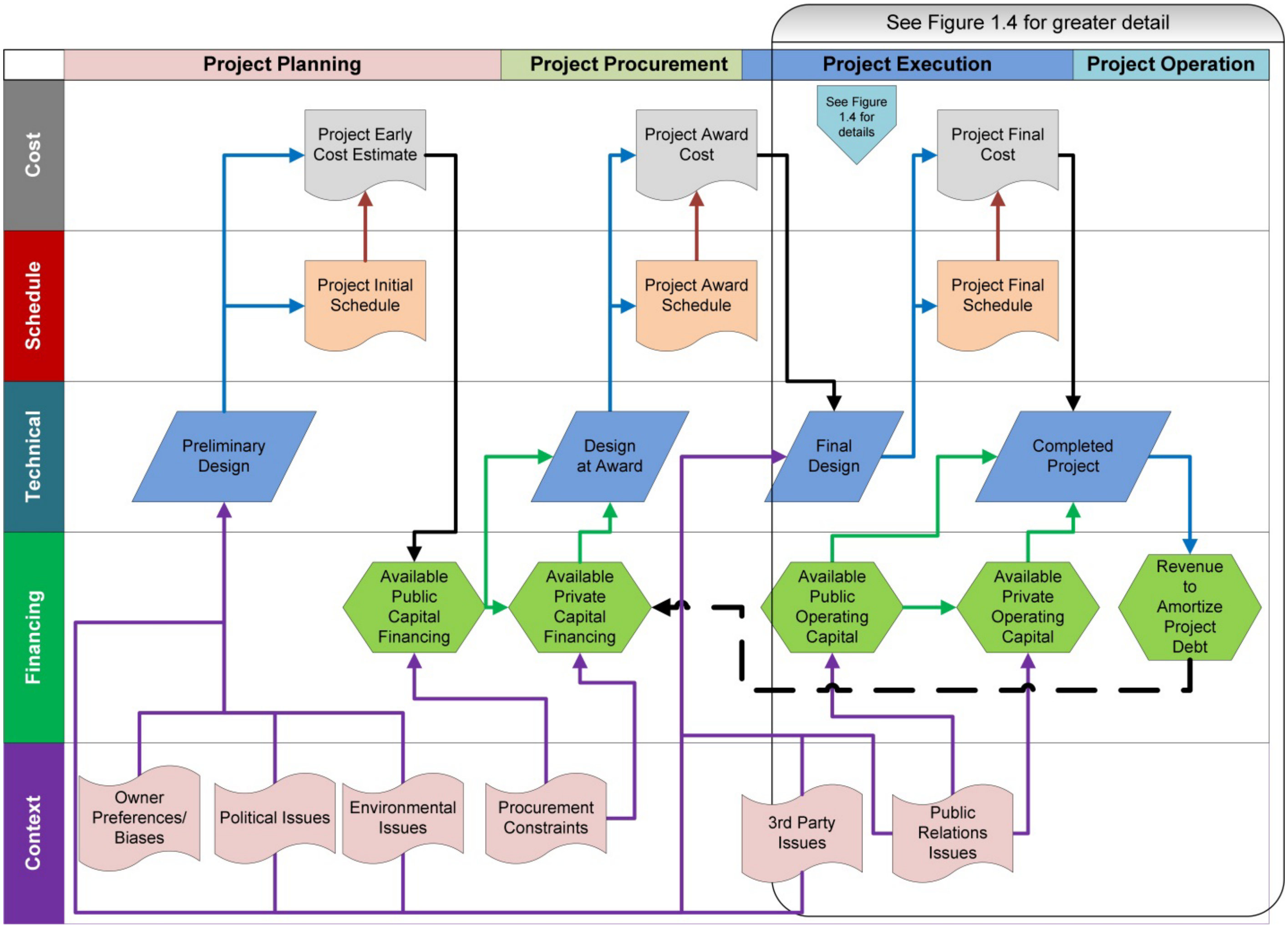


Figure 1.3. 5DPM model.

potential interacting contextual factors that explain differential success. Therefore, nonsuccessful projects were included in the analysis to facilitate the identification of contextual success factors.

For example, one factor of complexity is project delivery method. Another is public relations and support for the project. However, some agencies have aggressively adopted alternative project delivery methods, while others have been slow to change traditional procurement methods.

Some projects with strong public support have been difficult to implement because of technical or financial challenges. Other similar conundrums emerged from the literature review, and factors were identified that may explain the performance asymmetries.

The third step in the literature review was to establish clear, logical links between effective practices and outcomes. For example, effective practice strategies that led to successful expediting of government approvals may or may not be useful for creating innovative bridge designs. The knowledge framework created as a result of the literature review defined the most likely outcomes (e.g., managerial efficiency, engineering innovation, improved communications, expedited scheduling, skilled labor recruitment and retention) for each effective practice strategy.

Figure 1.5 illustrates the logic used to distill the knowledge on the state of theory and practice reported in the literature into a set of complex-project management implementation strategies, methods, and tools, which formed the primary outcome of Phase I of this research study.

With this understanding of the evolving nature of project management and sources of complexity in transportation projects serving as the organizing framework, a five-dimensional framework of project complexity was developed to guide the literature review task. Each dimension represents a source of project complexity and comprises numerous interacting project factors, as discussed in the next chapter.

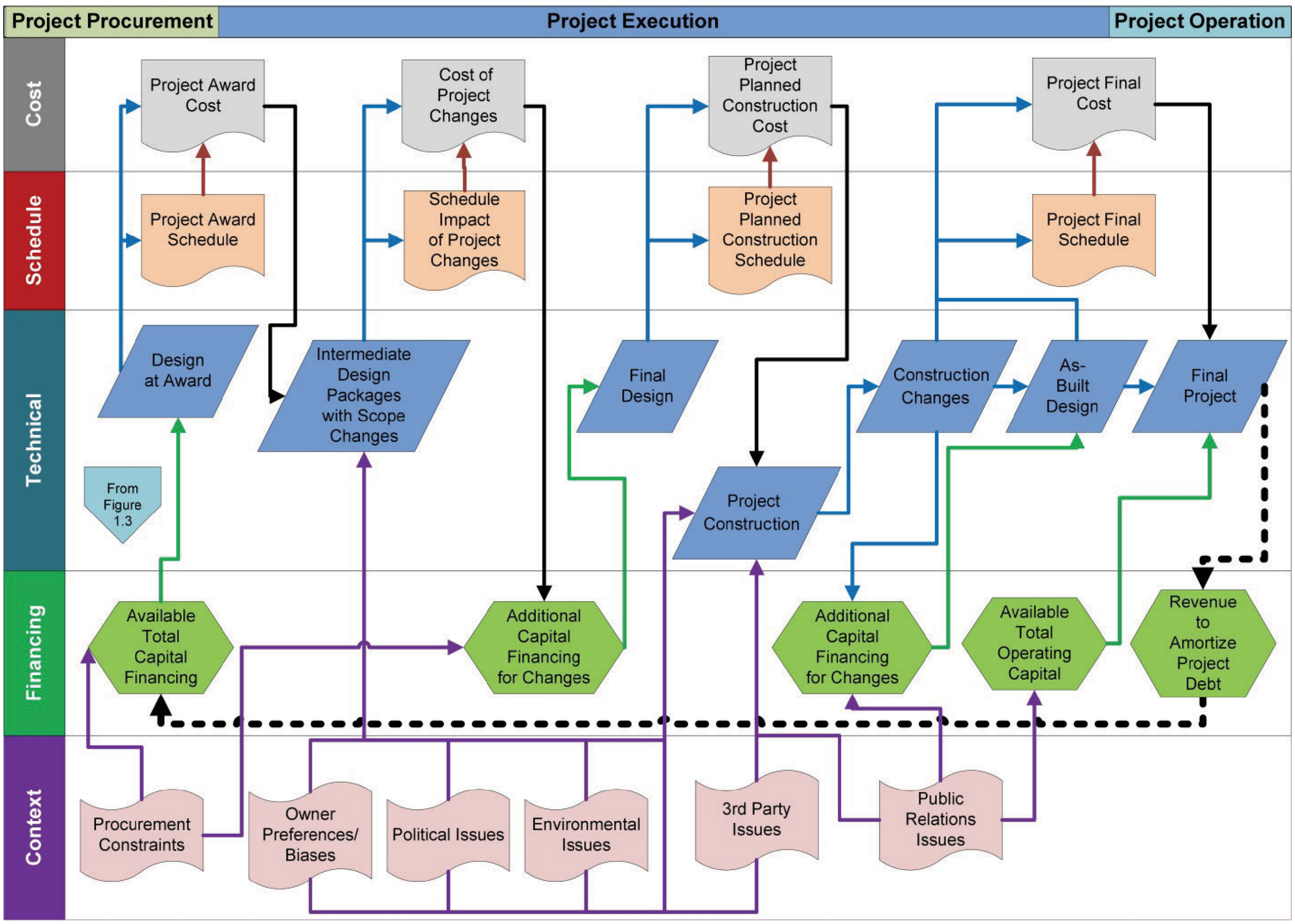


Figure 1.4. 5DPM project execution phase details.

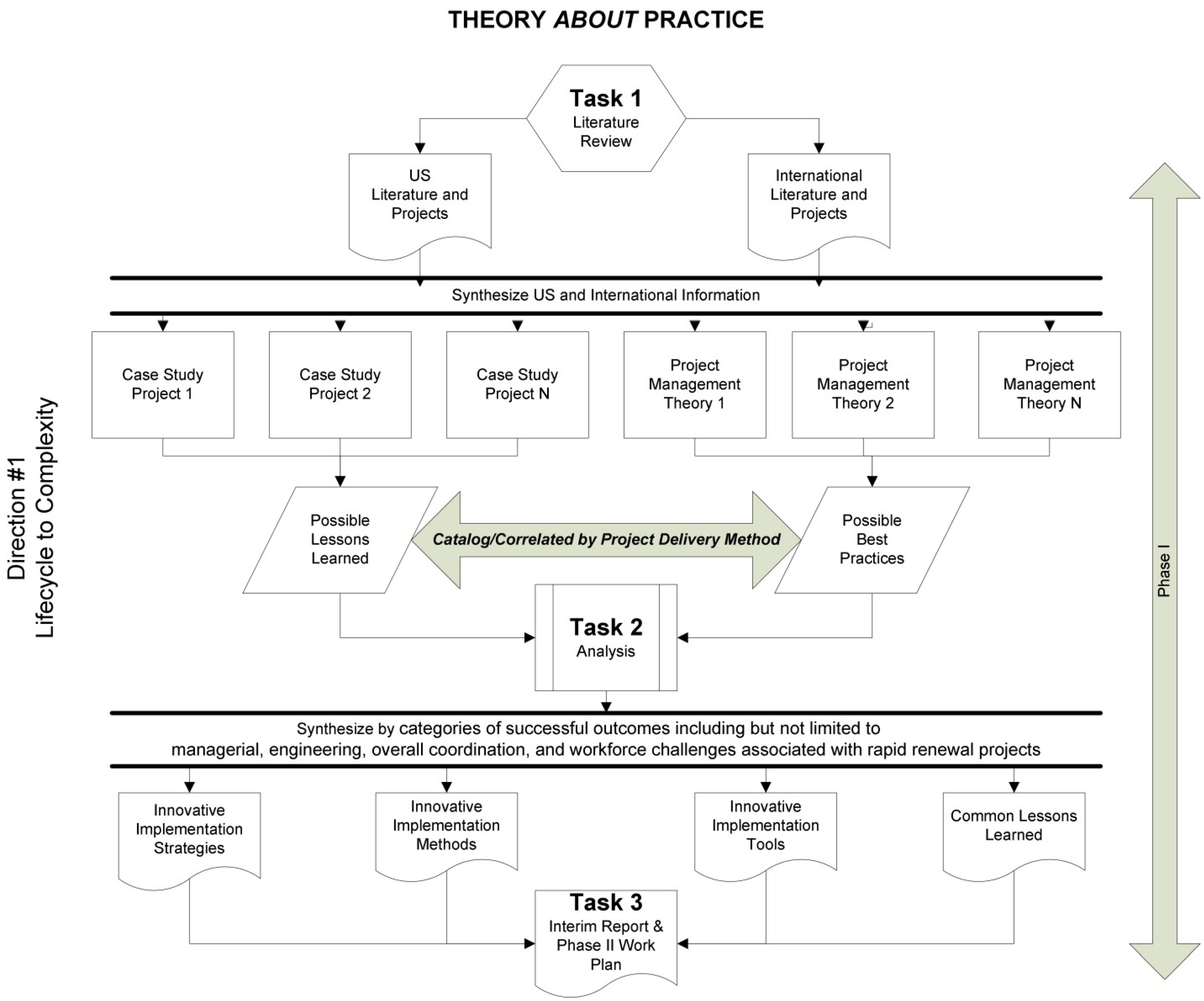


Figure 1.5. Complex-project management research framework for Phase I (Tasks 1, 2, and 3).

CHAPTER 2

Sources of Complexity and the Five-Dimensional Framework

The issues involved in researching and developing effective practices for complex-project management are themselves complex. To move forward effectively with the research project, the following parameters were established:

- The definition of what makes a project complex is best left to individual transportation agencies.
- The ultimate goal of the R10 project was to develop not only a guide for effective project management practice but also workshops and training materials to help transportation agency personnel manage complex projects more effectively.
- The research topic (complexity) is so broad that although execution of Phase 1 of the R10 project should be thorough, its completion should not be delayed unnecessarily by a perceived need for precise definitions or exhaustive literature reviews.

With these parameters as a starting point, a two-step plan for the literature review was developed. Step 1 represented a conceptual overview of the literature and industry experience aimed at identifying sources of complexity in modern transportation construction projects and understanding the changing nature of project management. The conceptual overview of the literature was summarized in the Introduction (Chapter 1), but the source material is discussed in more detail in this chapter (Chapter 2).

After identifying the sources of complexity and how they affect the changing nature of project management, the researchers analyzed the literature thoroughly to identity potential issues arising from each source of complexity. This fine-grained analysis of project issues is presented in Chapter 3.

Finally, the literature review assisted in developing a common understanding of which complex projects would be good candidates for Phase 2 of the study. In other words, the literature review helped define the nature of complex-project management for the purposes of the research study without an overly restrictive definition of complexity. Furthermore, the goal was to make future workshops productive by avoiding arguments over the definition of complexity, so this definition is left to the individual transportation agencies.

Project complexity is affected by many factors that the agency must control and manage to achieve success in an endeavor. As described in Chapter 1, five dimensions were identified:

- Cost
- Schedule
- Technical
- Context
- Financing

Each dimension has multiple factors that are grouped into categories. The objective of Phase 1 of this project was to analyze the literature examining the sources of complexity associated with these dimensions and to identify potential gaps in which no work has been performed regarding the particular factor(s).

The following sections of this chapter provide a summary and definition of each dimension of complexity along with its associated project factors. The project factors, independently, can create complexity, and for the purpose of organized discourse, each factor is discussed as a discrete event. However, it is important to note that the dynamic interactions among these factors are the true source of complexity.

The following sections also outline and categorize the sources of complexity within each dimension, as presented in the tables shown in Appendix A. Each dimension is broken into categories, and the factors under each category are identified and discussed as to how they can affect the complexity of the overall project. The basic structure of the organizational framework used in Phase 1 is presented in Figure 2.1 for clarity.

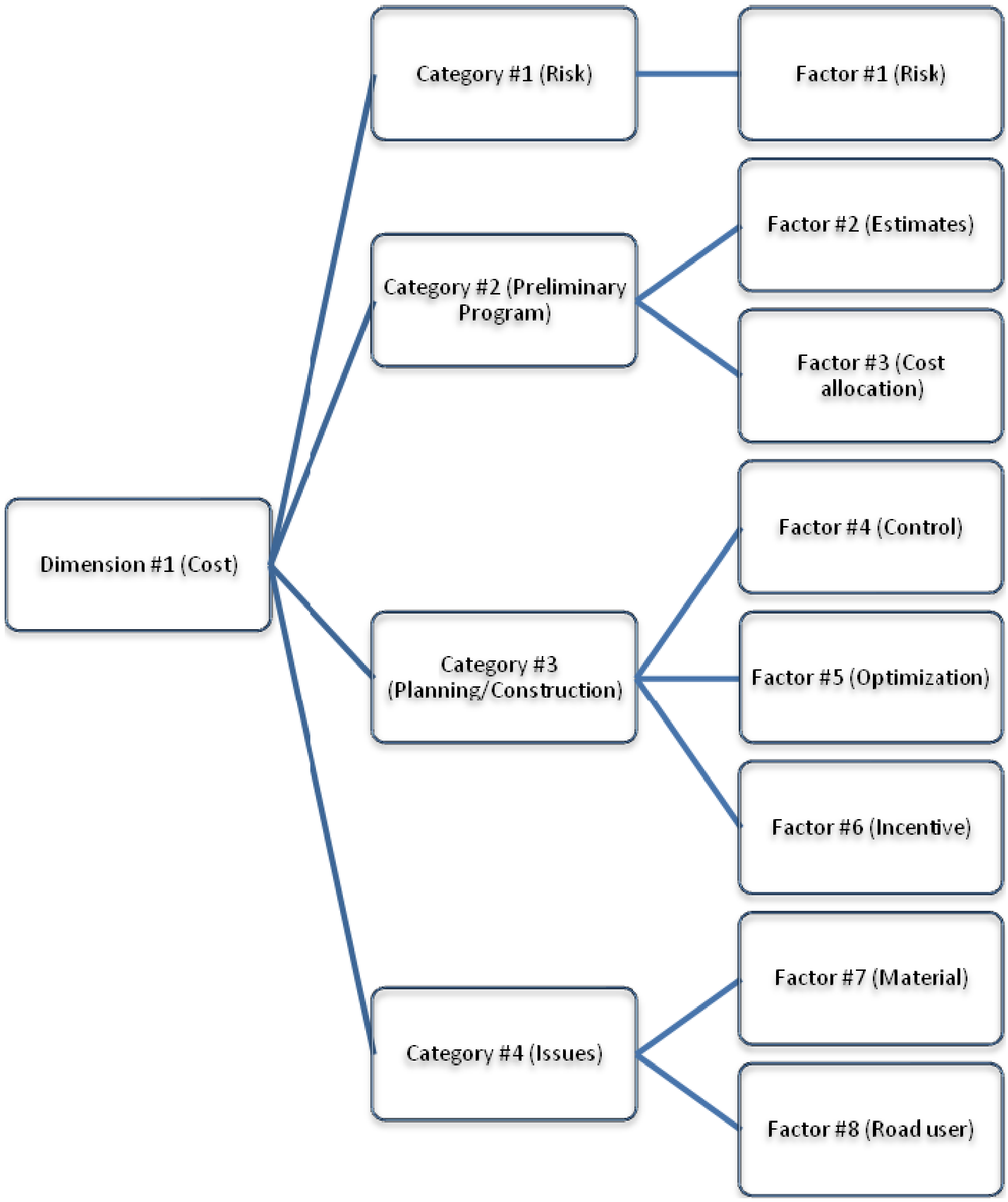


Figure 2.1. Sample organizational structure (cost dimension).

The structure is depicted for the cost dimension, but all dimensions followed a similar organizational structure. Some factors represent categories themselves because they do not fit with any of the other factors within the defined categories.

Cost Dimension

The cost dimension essentially quantifies the scope of the project in dollar terms. This dimension focuses on factors that affect cost growth, control, risk, and related issues and addresses how to plan for these management tasks during the preliminary stages and throughout the project construction. The specific factors for the cost dimension and the subsequent dimensions are discussed in this section.

Risk

Risk is a very broad category that is shown under the cost dimension but that can also be included with other dimensions. In terms of cost, risk is defined as having two factors: uncertainty and contingency.

Uncertainty is a risk associated with a project that cannot be clearly identified and quantified. The cost impact of various risk factors can be expressed in terms of insurance premiums, cost of allocating risks in contract clauses, and contingency budgets.

Contingency is the reserve budget (either allocated or unallocated) that is added to the overall cost estimate to account for unknown risks. Contingency can be added for all types of uncertainty, as was evident during the analysis of the literature.

Preliminary Program

The preliminary program category contains two cost factors: estimates and cost allocation. Estimates include conceptual, preliminary, design, and final estimates. Many different elements have estimates. These elements include right-of-way (ROW) costs, construction and design costs, and land-acquisition costs, to name a few. This factor encompasses all of the different kinds of estimates that are required and the susceptibility of those costs to varying from initial to final estimates. Cost allocation refers to the internal distribution of costs by the owner to make sure each area of project management has adequate finances for performing its operations.

Planning and Construction

Planning and construction include all of the cost factors that occur during these two stages. Although some planning occurs during the preliminary stage, these factors are more related to planning, or looking ahead, during construction of the project. Control, optimization, and incentive are the factors linked with this category.

Control includes all of the tools and methods used to control and manage costs throughout the project. Optimization is also included under the technical and schedule dimensions; but in a cost sense, it refers to the trade-off between cost, schedule, and quality. Reducing the duration of the project, for example, typically comes with a higher price tag. The incentive category relates to the owner's use of incentives for early completion of the project and must be accounted for when looking at the overall cost of the project.

Issues

Many issues are related to the cost dimension, but most have been discussed in text on the previous categories. The issues category relates specifically to the issues that need to be planned for up front and includes material and road user costs.

Material costs form an item that is estimated, but this factor focuses on the probability of the material costs changing as a result of market volatility. Because this factor has an external element, it is closely related to resource availability in the context dimension. However, because the material price volatility affects the cost of the project directly, this factor overlaps with the cost dimension.

Road user costs form another factor that goes hand in hand with determining the completion deadline of the project in the schedule dimension, but the owner must balance the cost trade-off between road user costs and the anticipated completion date, which explains its presence in the cost dimension as well.

Schedule Dimension

The project schedule is closely associated with the cost dimension. This dimension is affected by and directly affects the cost of the overall project, depending on management and decision making during the venture. The schedule dimension looks at variables, such as the overall time and deadline, risk, milestones, control, and problems associated with managing and planning for issues that arise before and during construction. The advent of new technology is also pertinent because it may affect the management of the project schedule.

Time

Schedule management is one of the primary responsibilities of the project management team. The process of preparing a realistic schedule for a project starts by identifying the project deadline and important interim milestones along the project timeline. Defining project activities and their relationships with other activities and project milestones and ensuring that each milestone is met are the next steps in preparing a schedule. Project delays and ways to limit delay are important topics within this category.

Risk

Risk is a major driver of project delays. A risk factor is any factor that has the potential to have an adverse effect on the project. In other words, risk is the potential for loss due to uncertain events. Each major risk factor can greatly affect the schedule of the project. Planning for schedule risk mitigation, by establishing schedule contingencies or having alternative solutions, is an important element of a schedule risk assessment.

Planning and Construction

Meeting schedule milestones and deadlines is one of the three main objectives of traditional project management. The process of project planning involves the determination of the resources needed to execute the project, when they are needed, and in what quantities. The planning and construction category covers the scheduling aspects of planning and covers milestones, control, optimization, and resource availability. Milestones are important deadlines during the project life cycle, and their occurrence in a timely manner is a requisite for project success.

Schedule controls are one of the most important duties of the management team. Various aspects of schedule controls include project management procedures, software requirements, reporting format, and frequency of reports. Optimization, which relates to the cost dimension in the context of the schedule dimension, is the trade-off between schedule, cost, and quality. Resource availability deals with the effective use of scarce resources and uniform usage, so that the need for hiring and firing of personnel is reduced.

Technology

Information technology and advancements in software design have created new opportunities for controlling project schedules. The technology category includes two factors for consideration: (1) visualization and (2) systems and software.

Visualization has been revolutionized by advances in hardware and software tools. Visualization allows the project team and the client to see the project before it is built and to make decisions based on new information that has not been available in the past.

Along with visualization is the capability of the system and software. Because of the technology boom, many different types of systems and software, all with different capabilities, are available. The main focus of these two factors is to address the issues associated with implementing new technology and, despite the advancements, the limitations of the systems and software.

Mathematical Modeling

Mathematical modeling refers to the development of a new method or a new extension to the scientific body of knowledge in the areas of scheduling and networking. Examples of mathematical modeling in scheduling are developing new algorithms for calculating optimal project duration, allocating scarce resources to various activities in such a way as to minimize project delays, and using decision tools for planning and scheduling multiple projects that need to be executed concurrently. It is acknowledged that this category is of less direct relevance to this research effort, but it does provide an overview of the scientific community efforts in this field.

Technical Dimension

The other common project management area typically identified as crucial to project success is the technical dimension. The technical aspects of the project include all of the typical engineering requirements.

Issues identified for this dimension include design requirements, scope of the project, quality of construction, and the organizational structure of the owner undertaking the project. This area also includes items such as contract language and structure and the implementation of new technology for effective management of the project.

Scope

Scope is a very broad term under the technical dimension that includes all of the project requirements. Scope is essentially the purpose of the project and, generally, what is going to be built to satisfy that purpose.

Internal Structure

The internal structure of the agency or owner is also its own factor and category, because the general organization of the entity is not necessarily project specific, although it can be, depending on the requirements of the project. This factor examines how the owner is set up to manage the project effectively (e.g., traditional hierarchy, matrix with project teams).

Contract

Under the contract category are four factors: prequalification, warranties, disputes, and delivery method. These factors need to be analyzed for problems contributing to complexity on each project.

Prequalification is the act of identifying qualified contractors and designers who are the most capable of performing the requirements necessary for the project. These approved parties can then be chosen on the basis of the selected delivery method for the project.

Warranties are a factor provided by contractors who ensure the quality and guarantee that pieces of the project will remain adequate for a specified period of time.

Disputes have been included in the contract category because of the typical chain of command for filing and resolving disputes that arise during the project, which is spelled out contractually.

The last factor within the contract category is the delivery method. The delivery method is the type of contracting approach used and may be limited by legislative requirements. Regardless of the delivery method used for the project, this factor also includes how the particular method is set up throughout the course of the project.

Design

The "design" of a project is a fairly self-explanatory concept, but different aspects of design are presented as factors and include methods, reviews and analysis, and existing conditions. The method refers to the process and expectations stipulated for the project by the owner and the accuracy and quality required incrementally throughout the design phase.

The method also refers to considering the entire life of the project and the anticipated maintenance requirements over its life span. The reviews and analysis factor is a method for maintaining accuracy and quality of the design and includes tools such as value engineering and analysis and constructability reviews. The existing conditions factor refers to any structural limitations already in place that need to be accounted for so the design will satisfy the solution required by the owner.

Construction

Quality, safety and health, optimization, and climate are all factors included under the construction category. Quality is literally the value of the work put in place by the contractors. Safety and health are concerned with maintaining a workplace in which all workers feel comfortable. Optimization, as noted in the cost dimension, is a trade-off between cost, schedule, and quality.

Increasing or decreasing one of these items has an effect on the others, and the overall expectations need to be taken into account when balancing the three. The last factor is climate. Generally, all parties need to be concerned with the typical climate at the project's location and the construction limitations presented by the area's typical climatic conditions.

Technology

The influx of technology has led to factors that project managers need to consider: usage, intelligent transportation systems, and automation.

Usage refers to what is needed for project communications, such as specific project management software, building information modeling, and others.

Intelligent transportation systems are another factor that may be necessary for transportation projects, and their use needs to be analyzed for implementation into the project.

Automation is the use of automated or robotic equipment for construction and, if desired for the project, needs to be specified and understood by all parties.

Context Dimension

The context dimension refers to all of the external factors that have an impact on the project and can be some of the most difficult factors to predict and plan for before and during construction. Context includes stakeholders, environmental issues, legal and legislative requirements, local issues, and project-specific factors.

Stakeholders

Stakeholders are the parties that directly affect and are affected by the project. The factors under stakeholders include the public, politicians, the owner, and jurisdictions.

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

Politicians may be involved during the financing and need stages and are likely to be involved if the project is not perceived well by the public.

The owner is the most obvious stakeholder and implements the project based on a need. The owner runs and manages the project and has the most to gain or lose from the project's success or failure.

The jurisdictional stakeholders are an all-encompassing group that includes any local, state, or federal organizations, such as the State Historic Preservation Office (SHPO), the metropolitan planning organization, and the FHWA. These entities may become involved in response to regulations and limitations encountered by the project.

Project-Specific Category

The project-specific category includes factors that directly relate to the project, including maintaining capacity, work-zone visualization, and intermodal requirements.

Maintaining capacity is a planning decision made by the owner, such as lane closures, detours, and time of construction activities (e.g., nighttime, weekends).

Work-zone visualization is based on maintaining capacity decisions and uses the appropriate means to alert the public of alterations to normal traffic routes and the presence of construction activity.

Intermodal refers to more than one mode of transportation and is a factor that must be addressed when planning projects involve or affect other modes of transportation.

Local Issues

Local issues constitute the broadest category of all the dimensions presented in the literature review. This category contains many factors for identification when undertaking a transportation project. These factors are social equity, demographics, public services, land use, growth inducement, land acquisition, ROW acquisition, economics, marketing, cultural aspects, workforce, and utilities. Many of these factors have elements that overlap other factors in the same category.

Social equity is a matter of maintaining equality between all social classes that use and are affected by the project. For example, a new highway project may be aligned to run through a lower-class neighborhood, possibly displacing residents who do not have the means to move elsewhere.

The location of the project also has an effect on growth inducement, land use, and the local economy. A potential project may spur growth and alter potential land use or change the zoning plan of the area, which then has a direct impact on the economy of the region. For example, the economy can be affected by a complete shutdown during construction or detours that bypass businesses.

In addition, the economy can be altered by the use of local labor (the workforce). The implementation of a project creates jobs directly and indirectly from the ripple-down effect. The local workforce factor is concerned with the skill and ability of the workers and the number of qualified entities that can fulfill the project requirements. Many of these factors overlap and affect each other.

The cultural and demographic factors are both concerned with how the project may be perceived by the public as a whole. The cultural factor relates specifically to the culture(s) of the area. Demographics outline the distribution of the population within an area and refer to the distribution of population that may be affected by the design decisions.

Utilities are a public service but are viewed separately because of their direct impact on the project. Utilities include all of the services necessary that may need to be moved and coordinated, such as electricity, gas, and so forth.

Public services, in this report, are considered to have an indirect impact on the project and include services that may have to be altered, such as emergency routes taken by fire and medical personnel.

The other two factors have been mentioned in the cost dimension but are noted here under a different premise. Land and ROW acquisition have costs associated with them, but external forces are the reason they are included under the context dimension. Both acquisitions may be hindered by the ability and process to acquire the portion(s) of land necessary for the project.

The last factor concerned with local issues is marketing. Marketing involves notifying the public of the project and its progress, particularly the matters that have a direct impact on the public.

Resource Availability

Resource availability is considered in this review to be its own category and factor. Resource availability is a broad category that includes all types of resources that may be needed for a project. Some of the resources identified may include material, equipment, and labor.

Material was mentioned in the cost dimension, but as a resource under the context dimension, it refers more to the ability to procure material based on demand rather than cost. Likewise, with equipment and labor, it is not about the cost but the ability of the parties to obtain the necessary resources. Labor, or workforce, was also mentioned under local issues, but in that context, it is meant as the capability rather than the availability of the workforce.

Environmental Category

The environmental category crosses over into other dimensions, categories, and factors. To confine the discussion, the researchers placed the environmental category within the context dimension. The impact of the environment as a whole is an external source of complexity, which places it in the context dimension.

The environmental category contains two factors: sustainability and limitations. The sustainability factor includes any materials, or requirements to use environmentally friendly construction materials, or desires by the owner to use alternative materials or methods. The limitations factor is essentially what type of environmental study is necessary for the project or any site-specific factors affecting the design and construction of the venture.

Legal and Legislative Requirements

Legal and legislative requirements are another category for the context dimension. Both procedural law and local acceptance are the factors acknowledged for this category.

Procedural law refers to the legal channels and limitations, such as permitting, zoning, and land acquisition, that constrain implementation of a transportation project. Procedural law is also the ability of an owner to use alternative delivery methods designated by law, such as design-build (DB) or construction manager at risk (CMR).

Local acceptance is 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.

Financing legislation is covered under the financing dimension; it is constantly changing and specifically applicable to that dimension.

Global and National Events

Global and national events may also increase the complexity of managing a project. Economics and incidents are the factors identified for this category. Economics was already discussed on the local level, but national and global economics may externally affect the project as well. Incidents refer to any recent events that have occurred nationally or globally that may have a positive or negative impact on the project.

Unusual Conditions

The last category under the context dimension is unusual conditions. Weather and force majeure are the two factors associated with unusual conditions. Climate was discussed in the technical dimension section under the premise that the typical climate is a factor that needs to be evaluated for construction purposes. Weather, on the other hand, represents unforeseen conditions that are abnormal and therefore preclude planning. Force majeure is related to weather, such as catastrophic events, but can also include events such as terrorism.

Financing Dimension

It is no longer sufficient to merely know the project cost. The owner must know how it will be paid for and integrate that knowledge into the project's scope of work. The mechanics of the financing can have a direct impact on the project's design, the speed of delivery, and the ability to achieve contextual requirements. One of the first steps in complex-project management is to identify available financing and the constraints inherent to the debt-servicing process.

Process

The process category contains four main factors: legislative, uniformity, transition, and project management training. Legislative refers to the legal limitations placed on financing methods. Uniformity deals with the consistency between states in legislation and financing techniques. Transition deals with financing complex projects compared with traditional project financing and the shift in financial planning. Finally, project management training is defined as the education that project managers need to understand financial methods.

Public

Public financing for complex highway projects is generally obtained from two sources, which are factors within the public category: federal funding and state funding. Federal funding is provided by the national government, is standard across the nation, and is derived from the annual transportation bill. State funding is financed independently through the particular state where the project is located.

The public category also includes three other factors: bonds, borrowing against future funding, and advance construction. Many complex public projects have financial contributors outside the traditional state and federal transportation funding, which is particularly true in multimodal projects.

Local sponsors are able to float municipal bond issues as well as other bond-based instruments. The FHWA is authorized to provide a number of innovative financial practices. One type is the Grant Anticipation Revenue Vehicle (GARVEE), which allows "states to pay debt service and other bond-related expenses with future federal-aid highway apportionments" (FHWA 2002). This instrument and others essentially allow states to borrow against future federal funding.

Another example from the FHWA's Innovative Finance Test and Evaluation (TE-045) program is a method allowing states to retire the costs of debt financing for infrastructure projects by using future federal aid.

Advance construction is also a method of federal funding that enables states to essentially borrow against future funding to finance needed projects. This method allows states to independently raise the initial capital for a federally approved project and preserve their eligibility for future federal-aid reimbursement.

Revenue Stream

The revenue stream category has three factors that are types of financing: revenue generation, vehicle miles traveled (VMT) fees, and cordon and congestion pricing.

Capital cost is often financed by some type of bond. Then, the revenue generated by the facility is used to retire the debt over a specified period.

VMT fees replace a traditional motor fuel tax by charging drivers directly for each mile traveled. Thus, VMT fees are a form of user fee and are perceived as less onerous than the fuel tax (Dierkers and Mattingly 2009).

Congestion pricing is used to reorient traffic demand from congested areas or during certain time periods by charging fees for use of highways during times of peak demand. Cordon pricing charges users to access a congested area, such as a city center, during specified hours. A few states use congestion fees, and some major cities have cordon pricing. However, both methods are used internationally as a means to reduce traffic demand and generate revenue (Dierkers and Mattingly 2009).

Asset Value

The asset value category of financing goes beyond deriving revenue to pay for a capital project. It treats transportation assets as vehicles for creating a revenue stream that can be used for the benefit of the agency. The asset value category contains three factors: monetization of existing transportation assets, franchising, and carbon credit sales.

Monetization of existing transportation assets is a method whereby an existing road or bridge will be brought up to some standard of quality. Private entities then are invited to take it over for a concession period, derive revenue from it, and return it to the original standard before turning it over to the agency or another concessionaire.

Franchising occurs when private companies are offered the opportunity to build and operate income-producing facilities, such as rest areas or fuel stations on the public ROW, in return for a portion of the profits. Typically, these revenues are used to finance routine projects on the route with which they are affiliated.

The sale of carbon credits is the last factor for this category. The carbon stored by trees and plants has a market value, and carbon credits can be sold to help finance the project.

Project Delivery Methods

The finance-driven project delivery methods category represents its own factor. These methods are driven by financial considerations and include public–private partnerships (PPPs) that include comprehensive development agreements (CDAs) and concessions.

Project delivery methods are different from the previous methods because they require the contribution of both public and private funding. At this point, it becomes difficult to differentiate between methods as they become so project specific that any attempt to develop a precise generic definition may be impossible.

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

Risk

A successful project requires mitigating the risks of cost overruns and of failing to meet the necessary fiscal requirements. Within the risk category, two techniques that are presented as factors are commodity-based hedging and global participation.

In the first technique, commodity-based hedging, the agency essentially locks in the material price at the earliest point when the required quantity is known. In the second technique, global participation, the agency takes 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 transportation projects.

CHAPTER 3

Literature Review and Analysis

The details of the literature reviewed are provided in Tables A.1 through A.5 of Appendix A. The literature focused primarily on research studies that examined factors of complexity in project management. An analysis of this literature is provided in this chapter, and the following sections identify several factors within each of the five dimensions of project management.

These factors have been established as major contributors to complexity in transportation projects and must therefore be controlled appropriately by the project manager to maximize the potential for success. Phase 2 of the R10 project used a case study methodology to identify specific project management responses to these complexity factors and to determine the effectiveness of the response, as discussed in Chapters 4 and 5.

Cost Dimension

Risk

Within the cost dimension, the risk category has been identified as a crucial element that must be planned for in transportation projects. The risk category includes both contingency and uncertainty factors. As shown in Table A.1 in Appendix A, nearly a third of all literature articles found refer to contingency risk, and about half refer to uncertainty risk.

The cost dimension factor issues tend to cross over and relate to other cost factors, such as material costs affecting contingencies, which ultimately affect estimates. The definitions of the factors outlined in Chapter 2 in the section on cost dimension will be used for simplicity in identifying problems associated within the cost dimension.

Traditional contingency estimation lacks consistency and uniformity (Kasi 2007). A major issue with contingencies is that they are based on an overall percentage of the total project costs and do not reflect the actual risks of the project (Allen 2004). Another issue is ensuring that contingency funds are used appropriately and that adequate contingency funds are available to keep the project within budget throughout its various stages (Sinnette 2004).

One type of contingency identified relates to material prices and the susceptibility of those prices to change throughout the course of a project (Gransberg and Kelly 2008). Bid quantity inflation as a means of providing contingency is another method that does not accurately reflect the requirements of the project (Gransberg and Riemer 2009).

New technology and contingency risks are becoming more prevalent and make it more difficult to quantify insurance requirements because historical data are lacking (Porro and Schaad 2002). There are many different types of contingencies, and a few are mentioned here. In summary, methods are being used that do not necessarily reflect the actual project risks and requirements, consequently devaluing the contingency assignation for the project.

Quantifying contingencies is a direct result of the uncertainties of a transportation project. High amounts of uncertainty in the budget and schedule of a project are the primary causes of cost escalation in major projects (Schneck et al. 2009). Identifying, evaluating, and quantifying the risks and uncertainties associated with the cost of a project are essential for effectively predicting and managing project costs (Lockhart et al. 2008).

Risk management systems are typically used for identifying uncertainties but lack structure and consistency. A consistent method should be able to quantify the cost of the risk and the probability of the risk occurring (Allen 2004). Identifying uncertainties by using project workshops is acceptable, but risk analysis should be ongoing and not based solely on preliminary checklists and risk registers (Edwards et al. 2009).

Preliminary Program

The estimates factor shows up in more than half of the referenced literature in Table A.1 (Appendix A). In a survey conducted by the Federal Transit Administration (FTA), almost

90% of large construction projects had budget overruns ranging from 13% to 106%. Optimistic scenarios yielding low estimates and high benefits as well as estimating errors were identified as reasons for the budget discrepancies. Accurate estimates for all required cost items are crucial for effective cost management (FTA 2003).

Estimates also present a major issue in Europe. Quotes or cost ranges are typically provided in response to public demand that reflect optimistic scenarios and bias during very early stages of project development (Hertogh et al. 2008).

In a report by the U.S. Government Accountability Office (GAO) concerning the management of large-dollar highway projects, many estimation issues were identified. The GAO states that initial estimates are merely preliminary and do not reflect the actual costs of the project. The costs are often modified throughout the project, are affected by inflation and scope changes, and the price is never actually set until the project is bid out (GAO 1997).

Future estimates need to be based on probabilities of expectancies in order to provide a range of costs with associated confidence levels. Traditional estimates provide one cost and do not always base it on the probability of unexpected situations affecting the initial estimate (Lockhart et al. 2008).

All of these issues identify why estimates are a major source of cost control in transportation projects. Keeping estimates current and up to date and identifying reasons for deviations are not always performed (Sinnette 2004, GAO 1997). Noting disparities for future use only compounds mistakes for future projects.

The construction process has many different levels of cost estimates besides the conceptual or preliminary level. Right-of-way (ROW) estimates for acquiring land, for example, affect the overall cost of a project. According to Anderson et al. (2009), many state highway agencies lack systematic and structured processes for ROW estimating and cost management. Having no defined processes affects the agency's ability to consistently produce ROW cost estimates that are accurate. The authors also state that ROW estimates do not typically involve ROW personnel and that there is little connection between ROW estimates and subsequent estimates. Kyte et al. (2004) indicated that some agencies incorporate estimation tools and procedures, but even when the methods have been identified for use, the techniques need to be monitored over time to ensure validity over a wide range of projects.

Cost allocation within the owner's organization is the last factor in the preliminary cost category. "Cost allocation" is defined as the distribution of resources to the divisions that are needed to complete the project. The Tennessee DOT has recognized that managing and tracking funding and resources and streamlining the allocations of the funding to the appropriate areas are needs for the future (Brown and Marston 1999). Dividing the costs into groups for which intent and purpose are clearly evident and providing a logical structure for the function of cost distribution are issues that need to be transparent and efficient for effective project management (Kasi 2007).

Planning and Construction

Throughout the course of a construction project, many events can take place to alter the cost. Cost control is a factor that includes all methods used to manage the cost of a project. Project managers need to use cost control methods to identify and mitigate issues before they arise. A good control system is only as effective as the accuracy of the information input into the system (Gray and Larson 2008).

Cost validation at defined milestones should be performed for effective cost control management (FHWA 2009a). One method of cost control is design-to-budget. Owners need to be careful about adopting this method; initial estimates must be realistic to allow for a budget that fits the required project scope (Casavant et al. 2007). Specifically, ROW cost control is used sparingly during the early acquisition stages (Anderson et al. 2009). As discussed in the last section, estimates must be realistic for cost control measures to be effective.

Control also relates to what type of constructability reviews, value engineering, and value analysis is performed during the project (FTA 2003). Determining when to hold constructability reviews, value engineering, and value analysis sessions is essential for ensuring that these cost control methods occur (FHWA 2009a). In addition, time during these sessions is not always spent on the items that have the highest potential to affect the overall project costs (Sangrey et al. 2003).

Evaluating the design for cost savings and potential issues helps in alleviating potential cost factors that will need to be controlled. Although the FHWA does recommend the use of review and value sessions, it does not particularly focus on cost control as a crucial management tool after initial planning stages.

Along with the FHWA, individual states use different philosophies for cost control measures. State agencies typically do not track the overall cost of the project because each segment of the project is financed separately and treated as an independent project. Data and reasons for cost overruns are not readily available, and agencies record the costs, but typically not the reasons, for discrepancies between estimates and actual costs (GAO 1997).

Optimization is one factor that appears under the cost, schedule, and technical dimensions. For the cost dimension, only cost trade-off issues are identified. Minimizing costs may be the focus, which would then directly affect the construction schedule and quality of the work performed (Cristobal 2009). Reducing the construction schedule typically increases the cost, and project managers need to be aware of the project status and budget before making decisions about optimizing one dimension or another (Sorel 2004b).

One method for controlling costs is to create incentives for the concerned parties to have a stake in controlling cost; however, the methodology is not clearly defined. The established method for setting up shared-risk contingency accounts needs to be clearly outlined (Allen 2004). The FTA also states in its project management guidelines that establishing who is responsible for cost overruns can create an incentive for those who bear overrun responsibilities (FTA 2003). Incentives need to be used carefully so that the entire project is the focus of the parties bearing the shared risks (Hertogh et al. 2008).

Issues

Material costs are a factor that can arise under the issues category. In Table A.1, Appendix A, two articles identify material cost as an issue for complex projects. Construction material price volatility has increased more over the past 3 years than it has in the last two decades, subsequently requiring cost engineers to need better tools to enhance the accuracy of the estimates (Gransberg and Kelly 2008). The FHWA's cost-estimating guidance also states that material price volatility can cause issues for controlling costs. Without the acquisition of firm bid prices, speculation and bid inflation may occur, resulting in over- or underbudget projects (FHWA 2007b).

The last factor within the cost dimension is the issue of road user costs. User costs need to be compared with the desire to finish the transportation project earlier, which would increase the actual construction costs of the project (Sorel 2004b). Project managers need to identify the trade-off between construction costs, road user costs, and the construction schedule to balance the impact on the public and make an appropriate decision.

For a project in Canada, it was decided to accelerate the demolition schedule, which resulted in increased costs but less impact on road users. The benefits need to be compared to the increased costs before any such management decisions are made (Martin and Does 2005). As shown in Appendix A, the referenced articles are the only research pertaining to user costs, so there appears to be a gap in the research for this factor.

Schedule Dimension

Time

The issue of time has appeared in the literature within two contexts: scheduling the project and project delay.

Scheduling and planning form one of the management team's most important tasks. A well-scheduled project eliminates many of the problems encountered during the design process and becomes a valuable tool for project managers during the construction phase (Dolson 1999). However, poorly scheduled projects may result from some project champions' desire and eagerness to have their project approved for funding, yielding optimistic schedule estimates that are not realistic (Flyvbjerg et al. 2004, Butts and Linton 2009).

A procurement plan should be prepared (FTA 2003) and the timing of the value engineering and constructability reviews should be established (FHWA 2009b) on the basis of the developed plan and schedule. The issue of managing the project schedule is often discussed along with project delays in technical literature because of the impact that delays will have on project success.

Many of the references use schedule performance as an indicator of project success and of a project manager's performance (Ashley et al. 1987, Sanvido et al. 1992). A recently completed NCHRP project reviewed the performance of more than 26,500 state DOT projects in 20 states during the period from 2001 to 2005 and found that only 35% of these projects were delivered on time (Crossett and Hines 2007). In an earlier study, Thomas et al. (1985) found that about one-third of public highway projects suffered from delays and that the average delay for highway projects was 44% of the original contract time.

The situation is not better internationally. A recent study of 65 highway projects in five continents sponsored by the World Bank from 1991 to 2007 found that schedule performance in these projects was poor, with 57 projects (88%) showing an average delay of 35% of the original duration (Gamez and Touran 2009). Transportation project delays are common in the United States and abroad (Gamez and Touran 2009, Crossett and Hines 2007, Booz Allen Hamilton 2005, Thomas et al. 1985).

Loss of momentum during the project life cycle causes even more delays and makes effective management of project delays one of the most pressing issues. Some of the causes of delay are discussed under the risk category. About 25% of the references that were related to schedules discussed time and delay issues.

Risk

One of the major problems associated with schedule risk is the inability of analysts and managers to estimate the impact of each risk item identified on the duration of the project (Golder Associates, forthcoming; Touran 2006; Molenaar 2005). As mentioned within the cost dimension, contingency is a method for accounting for unforeseen circumstances. The same issues arise within schedule risk in that it is difficult to quantify how much contingency is appropriate for the project.

The direct schedule risk is not the only issue; indirect risks are also tied to the project duration. Project delays result in low morale, rework, and wasted efforts in many instances, all of which should be considered when analyzing the potential risks and outcomes of the schedule duration.

In other words, project delays and cost overruns are highly correlated (Butts and Linton 2009). Project delays affect both the planning and design phase and the construction phase. In fact, the delays during the planning and design phase will affect the construction phase and project cost (Flyvbjerg et al. 2004).

Sources of complexity related to schedule risk can be found mainly under the context, technical, and financial dimensions. Examples of these risk factors include the real estate acquisition process, delays in obtaining various permits, and delays in funding approvals at the local and federal levels.

In the literature review, the risk category was mainly associated with probabilistic estimating and scheduling (FTA 2003, Sangrey et al. 2003, Booz Allen Hamilton 2005, Kerzner 2006). Using probabilistic modeling and the Monte Carlo simulation is a relatively recent trend for establishing contingency durations for large infrastructure projects.

Other sources emphasized the importance of establishing realistic contingencies for the project (Hertogh et al. 2008). More than a third of the sources reviewed for the schedule dimension discussed risk analysis and contingency planning.

Planning and Construction

Planning the design effort and the construction phase of the project is a prerequisite for a successful project (Lam et al. 2008, Ashley et al. 1987). Project milestones and the plans for each were reviewed. Kerzner (2006) contends that the most important difference between a good project manager and a poor one is described in one word: "planning."

A well-organized, cohesive team to manage, plan, design, construct, and operate the facility is found to be essential to project success (Sanvido et al. 1992). Lack of careful planning efforts will result in poorly prepared schedules that do not account for sufficient floats along major schedule paths, do not follow proper scheduling guidelines for preparing the network, and will eventually create overly optimistic and untenable milestones. Projects that require multiple contractors depend on all parties' meeting certain milestones. Small delays can cascade into major schedule slippage that can greatly affect the overall duration of the project (Touran et al. 1994).

Effective project controls are another factor under the planning and construction category. Design and construction phases need to be evaluated vigorously and controlled on a continuous basis. Some of the measures that have an impact on the control of schedule include the frequency of personnel meetings, the experience of the project manager, and the time the manager devotes to the project (Kog et al. 1999). Independent validation of cost and schedule at various phases of the project must be conducted to obtain a realistic status of project schedule performance and to plan for potential issues (FHWA 2009a).

Optimization is another factor that is considered part of planning and construction. Optimization routines allow flexibility in project scheduling and in expediting the schedule. Cristobal (2009) notes three desirable objectives for effective project management: minimize time for meeting quality and costs objectives, minimize costs subject to quality and time objectives, and maximize quality while meeting time and cost objectives. The FTA (2003) believes that executing effective value engineering and constructability reviews helps optimize project objectives.

Another factor reviewed under planning and construction is resource allocation. Resource allocation involves scheduling scarce resources to minimize the resulting delays. Resource availability applies to labor, equipment, and material. Labor shortages during the course of a project have a significant impact on the delays of a transportation project (Merrow et al. 1988). During construction, one driver of schedule delay is poor planning for long-lead items. These resources may have limited availability and may ultimately affect the subsequent construction activities. Resource availability has the potential to alter the flow of work and generally limit the options of the management team (McKim et al. 2000). Resource availability is discussed in six references for the schedule dimension (Table A.2, Appendix A).

Technology

New software systems allow the project management team to effectively plan for and control activity durations as well as manage resources and cash flow through innovative methods and visualization techniques. Furthermore, the advent of the techniques of four-dimensional (4-D) modeling (Fischer 2000) and building information modeling have created an integrated environment for project planning, design, and control.

The technique of 4-D modeling has established the importance of time along the other three dimensions that represent quantities and volume of work. This linkage of schedule activities to work components is done in a visual manner that facilitates the process of planning for upcoming events and resolving potential conflicts. Impediments to more widespread use of 4-D modeling include the high development cost [General Services Administration (GSA) 2009]. In addition, 4-D models require intimate interaction among project team members that may not be possible under traditional project delivery methods. In general, delays tend to occur when new technology is being used on a project for the first time (Merrow et al. 1988).

In general, software systems have contributed significantly to the capabilities of the project manager. Many of the modern management approaches in planning and control of projects, including earned value analysis, resource allocation, optimization of schedule, and probabilistic scheduling, would not be feasible without the benefit of current software systems (McKim et al. 2000).

An overall conclusion from the literature search on software systems was that software capabilities do not appear to be a major issue in achieving project management goals. Although many researchers and practitioners have commented on the effective use of software systems, they do not seem to think that the problems of the project manager in complex projects can be solved with more-powerful software.

Mathematical Modeling

Many of the technical articles on scheduling deal with developing new mathematical algorithms for optimizing some aspect of schedule or resource usage and allocation. This emphasis is partly due to the nature of most technical journals, which place value on expanding the existing body of knowledge. Although these endeavors are valuable in academic circles, their applicability and usefulness for training project managers of complex projects are less evident.

Many of these proposed models and concepts will take several years to be functionalized. Yet, to ensure that the project team performed a comprehensive literature search on this topic, it reviewed examples of references dealing with mathematical modeling. Examples of the more-recent contributions in the field include works by Khodakarami et al. (2007), Christodoulou et al. (2009), and Cristobal (2009), in which authors have used Bayesian updating, integer programming, and other mathematical tools to optimize project schedules.

Recent developments in software automation and use of computer-aided design and 4-D modeling have been reported by Feng et al. (2010), Russell et al. (2009), and Jongeling and Olofsson (2007).

Technical Dimension

Scope

Quite a few articles discuss scope as one of the major issues associated with technical factors. The FHWA provides a framework for preparing a project management plan that would serve the agency carrying out the project. The first thing that the FHWA mentioned for the project management plan framework is that the scope should be clearly defined (FHWA 2009a). The FHWA also stated that each project should have a scope management plan. Miller and Lantz (2008) revealed through a literature review and interviews with transportation agencies that scope should be defined during the planning process based on the purpose and needs of the project.

Internal Structure

One issue concerned with project success is how the internal structure for the owner is set up to manage the project effectively. This organizational setup has been one of the major subjects for improved project performance.

Tatum (1984) reported that more-systematic organizational design indicates an opportunity for improved performance. In the same year, Levitt (1984) suggested that defining new organizational forms and integrating managers into new organizational structures can reduce the pain of managing complex projects.

Another issue relates to the established lines of communication that have been mandated not only internally but also with contractors and designers. Research shows that definitive lines of communication are a major issue in completing the project on time, within budget, and without litigation (Pate 2000).

Contract

The subject of identifying qualified contractors and designers who are most capable of performing the requirements necessary for the project has been identified as a major issue by many researchers. The FTA highly recommends prequalification of bidders to verify that proposers are capable of performing the work (FTA 2003). Pate (2000) and Beard et al. (2001) also identify the use of prequalification to help meet the objectives of the project.

However, few articles discuss how prequalification should be carried out. Specific guidance is one area necessary for each project in terms of the agency's quality management approach (in its policy documents) to ensure that quality is properly emphasized throughout the project life cycle (Gransberg and Windel 2008, Gransberg et al. 2008).

Only one article related to the technical dimension discusses warranties. McClure et al. (2008) concluded, through the case study of a highway project that used PPPs as a delivery method, that performance warranties have an effect on the success of a project. The research also suggested that independent verification of the warranties is a factor for project success. As shown in Table A.3 in Appendix A, this article is the only research found that identifies warranties as a problem for complex factors, so research in this area appears to be limited.

Disputes and litigation are a major factor that has the potential to affect the cost and schedule before, during, and after a project. 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 (Schexnayder and Mayo 2003). Disputes should be dealt with before they develop into claims, and the administrative process should be outlined (Abdul-Malak and El-Saadi 2000). The contract language is one aspect that should be examined, and chosen, to demonstrate the dispute resolution process outlined by the owner.

The literature review revealed many articles that discuss the delivery method as one of the major issues associated with the contract category. A third of the articles that related to the technical dimension identified the delivery method as a major factor for project success.

Many articles compared project performance between delivery methods. Thus, understanding advantages and disadvantages of each project delivery method is essential for better performance.

Yakowenko (2004) stated that no single project delivery strategy is appropriate for all major projects, and contracting agencies should consider the merits of each method in relation to their project needs. Konchar and Sanvido (1998) compared delivery systems, such as design-build, design-bid-build, and construction management, in terms of quality, cost, and schedule. Regardless of which delivery method is selected, the process and structure are two issues that affect the success of a project.

In particular, Molenaar et al. (2000a) pointed out that the use of the design-build approach needs to be clear and transparent so that all parties understand the process. Partnering on a project can also be an effective method if all participants are fully engaged in the process, understand the partnering process, and are willing to work in positive relationships with each other (Schaufelberger 2000).

With the use of alternative delivery methods becoming more prevalent, owners need to be clear about the selection process and state the project requirements, regardless of the delivery method that is chosen.

Design

The design method refers to the process and expectations stipulated by the project and the accuracy and quality required incrementally throughout the design phase. Sometimes, the design method is outlined to alleviate specific problems such as environmental concerns (Trapani and Beal 1983). The design method was selected as one of the critical success factors by Sanvido et al. (1992) and Ashley et al. (1987). Identifying the requirements of the design method is a subject that should be outlined for the project to proceed initially from the design phase and maintain consistency throughout the project.

Review and analysis methods are used to maintain the accuracy and quality of the design and include tools such as value engineering and analysis, constructability reviews, and environmental reviews by the involved parties and/or consultants. The owner needs to decide the level at which to incorporate reviews and analysis methods throughout the course of the project.

Review and analysis methods may be a tool for examining ways to accelerate highway projects by reducing the average amount of time required for the design, review, approval, and construction planning phases that can be a barrier to rapid renewal (Bernstein 1983). As a strategy, value-engineering techniques are used to enhance overall project performance. Value engineering and constructability reviews are beneficial to the project performance, but the timing of the value engineering and constructability reviews is important and should be defined in the plan (FHWA 2009a). Determining when to hold constructability reviews is crucial for project success (Pate 2000).

The existing conditions factor refers to any structural limitations already in place that need to be accounted for in the design to satisfy the solution required by the owner. Several case studies were found concerning existing conditions.

Martin and Does (2005) described the process of a bridge demolition project and its effect on the public. This case study identified issues that need to be considered for the success of the project, such as considering various alignments to avoid removing the existing structure, accelerated removal time to minimize the impact to the public and avoid costly and lengthy detours, and a detailed demolition plan for the safety of workers and surrounding structures. Depending on the existing conditions for a project, many issues may arise that need to be dealt with to achieve successful project completion.

Construction

Within the construction category, quite a few articles identify quality issues as a factor for the management of complex projects. In an attempt to provide comprehensive guidelines for the project and construction management of FTA projects, a couple of issues concerning quality became apparent.

First, updating comprehensive project management plans has the potential to affect project success at every stage of the project. The FTA also states that the structure of quality assurance and quality control programs should be outlined to ensure proper implementation and to identify possible cost-saving methods and alternatives (FTA 2003).

Research reports mention quality of construction as an issue for specific delivery types. Gransberg and Molenaar (2004) analyzed 78 design-build projects and discussed the required use of quality management programs for maintaining minimum quality levels during design and construction. Mandating that quality management programs are proposed and implemented throughout the course of the project has a large impact on the success of the design and construction quality.

Little research pertained to projects that had problems solely with safety and health issues. However, these issues can have serious impacts on projects. According to Gambatese's (2000) research concerning the owner's involvement in safety, unsafe practices not only affect peoples' lives but also create cost overrun and schedule delays.

Safety records may be used for contractor performance-based prequalification practices and may limit the number of bidders that meet acceptable standards. On the design side, highways may not be reconstructed as originally designed because of increased emphasis on safety standards, and this could increase the costs of highway projects (Dallaire 1977).

Cristobal (2009) discussed optimization among technical factors as a trade-off between cost, schedule, and quality. The article presented a model that could optimize cost and schedule while maintaining a minimum degree of quality. The issue related to cost and schedule is that quality should always be considered when the agency decides to accelerate the project schedule or reduce costs. This article is the only one that identifies optimization as a potential issue, and research appears to be limited for this factor.

The last factor in the construction category is climate. As defined in Chapter 2 of this report, this factor pertains to the typical climate of a region that may present management challenges that need to be planned for. As shown in Table A.3 in Appendix A, no research was found that classifies climate as an issue for the management of complex transportation projects.

Technology

New technologies have a higher risk profile and need to be managed according to the specific needs of the project or of an innovation (Hertogh et al. 2008). Not many articles were found under the category of technology, except for usage, which is what is being used or is specified to be used for project communications, such as specific project management software, building information modeling, and others. Articles discussing intelligent transportation systems or automation were not found through the literature review.

The subjects concerning usage included 4-D modeling (Fischer 2000), paving quality control systems (Cho et al. 2009), high-resolution automated cameras (Bohn and Teizer 2009), context-sensitive solutions (Olszak et al. 2007), and when and how to specify usage of these technologies and others that may arise in the future.

Context Dimension

Stakeholders

Hertogh et al. (2008) indicated that stakeholder management is critical for a project and that stakeholders should be categorized by their impact on the project.

The literature review identified many articles that discuss the public as one of the major issues associated with stakeholders. More than half of the articles relating to the context dimension identified the public as a major factor for project success.

The FTA has produced a comprehensive set of management guidelines and states that involvement by the local community is essential at every stage of the project development, from planning through construction (FTA 2003). This large government agency has identified that public involvement must not be taken lightly and should be incorporated throughout all stages of the project life cycle.

Another issue concerned with public satisfaction is the need for projects to be transparent in reporting and decision making and to not hide negative components of the project. Maintaining public support and exemplifying that the public's resources are being used on a worthwhile project are major components of project success (Capka 2004).

Many different types of stakeholders are involved with construction projects. One of the most important parties is politicians in relation to the subsequent legislative process. Politicians define the process that must be adhered to when an agency plans construction projects. The political process and obtaining approvals from the stakeholders are a major cause of delay and overruns (Booz Allen Hamilton 2005).

As can be seen in the Transportation Association of Canada (TAC) briefing (2009), political interest arises when the stakeholders are unsatisfied with repeated congestion, a lack of environmental consideration, and shortfalls in transportation financing. Controlling the political process and satisfying politicians have the potential to affect project success. Heavy pressure can come from politicians to minimize traffic disruption and accelerate the project (Crichton and Llewellyn-Thomas 2003).

The owner is the stakeholder responsible for making decisions that affect the entire process and the flow of communication. The owner is also accountable for determining which projects to undertake and for defining the need for a particular project.

The culture of the organization can affect the ability of project managers to effectively complete the project (Gray and Larson 2008). Decisions made by the owner affect the other stakeholders, and the process can be an issue, depending on the level of definition. All projects have the potential for concerns, depending on the procedure for outlining responsibilities and lines of communication (Gray and Larson 2008). The organizational structure can be a major barrier and affects the project throughout the life cycle.

Depending on the type of project, jurisdictions may become involved. As defined in Chapter 2, jurisdictions are any external organizations that are affected by, or have the probability of affecting, the project.

Dating back to the 1960s, average project time has grown, and jurisdictional review time is a factor that affects the length of the project (Bernstein 1983). Jurisdictional reviews are not a new problem; they have been around for a while.

In light of new environmental regulations, one of the major problems facing project managers is limited resources within the jurisdiction and lack of knowledge about each other's roles and processes (GAO 2008). Involvement of external agencies can be difficult to obtain. Either there is a lack of staff, or the agencies are unable to provide meaningful input (Miller and Lantz 2008).

When constructing large infrastructure projects across multiple borders, priorities and commitments may vary, causing a loss in project value until the entire project is completed (Hertogh et al. 2008). The incorporation of jurisdictions into the construction process is a definite issue that affects project management.

Project-Specific Demands

According to a few different case studies, maintaining the capacity of the existing transportation was an issue while demolishing and constructing new facilities. Determining the process for minimizing the impact to the public and avoiding costly and lengthy detours was a focus on a bridge demolition project in Canada (Martin and Does 2005).

Depending on the type of project, capacity may need to be maintained around the clock. A border-crossing station between the United States and Canada had to select an alternative that allowed the traffic to flow 24 hours per day, 7 days per week (Chiu and Teft 2006).

Establishing what can be done to allow capacity to be maintained is a crucial component and has many ramifications. Developing a successful traffic management plan and selecting the most appropriate types of lane closures for the job affect the productivity of the work and completion of the project (Lee et al. 2000).

Along with maintaining capacity, ensuring that work zones are properly distinguished is important for the safety of workers and the public. Alerting the public to altered routes and clearly labeling work zones are vital issues for taking advantage of opportunities and meeting expectations (Sorel 2004a). The public needs to be informed of the project, and methods for communication need to be defined.

Ensuring that contractors are aware of the need to carry out work-zone visualization practices has been noted in Canada. Visualization is a tool that could be identified and used in planning (Martin and Does 2005).

The other project-specific issue is whether multiple modes of transportation affect the planning and constructing of the project. One major problem with intermodal transportation projects is the multiple groups and budgets that need to be accounted for during the project (Broadhurst 2004). Considering the alignment used for the project, relocating existing modes of transportation, such as rail lines, may be necessary (Crichton and Llewellyn-Thomas 2003). Coordinating relocations must happen between multiple parties and can affect various modes of transportation.

Local Issues

When implementing a transportation project, the public is one of the stakeholders affected, as described earlier. The project has the potential to affect the public in various ways, depending on the decisions made. One common perception of transportation projects is that outsiders will benefit more from the project than those directly affected, as defined by the term "social equity" (Barnes and Langworthy 2004).

Social equity is also an issue in the United Kingdom where projects can disadvantage certain groups and, depending on the location of the project, noise and air pollution can affect groups differently (Davies and Binsted 2007). When considering toll infrastructure, pay systems have been noted as possibly affecting social equity in Canada (TAC 2009).

Social equity is a broad issue, and many issues stem from project decisions that can affect various parties differently throughout the world. It is important for the owner to identify the social problems that will be created and solved by the infrastructure project (Hertogh et al. 2008).

Issues related to social equity are demographics, public services, land use, and growth inducement. These issues are similar to social equity, and all can be affected by the project decisions made.

Demographics refer to the distribution of population in an area where a project is planned. Public services deal with how the project affects emergency routes. The location of the project may also end up affecting land use and zoning plans and possibly spur growth inducement as well. Thus far, no research has been identified concerning these four issues.

The land acquisition factor pertains to any land that must be procured for the project, including ROW purchases. While reengineering its project development process, the Tennessee DOT identified acquisition of ROW as an area that needed to be improved and found that current legislation can create a barrier for acquisition (Brown and Marston 1999). The method for acquiring ROW was also identified as a barrier to project success on a complex project in Colorado (Broadhurst 2004).

In Canada, land acquisition has also been pinpointed as a process that needs improvement, but agreements for procuring publicly owned land held by historic and tribal agencies have added to the complexity of acquiring land for a project (Chiu and Teft 2006).

The impact of a construction project has the potential to greatly affect the local economy. In a study that identified five areas that are crucial for measuring project success, economic issues were found to be important (Ashley et al. 1987).

In Europe, the project as a whole must be conceived on the basis of the economic benefits of the project and not just on that of the completion of the project (Hertogh et al. 2008). In terms of social equity, tolls also play an important role in the economy of the region, as noted in Canada (TAC 2009). However, as indicated in Table A.4 in Appendix A, past research on the effect of a transportation project on the local economy is limited at this point.

One major factor that relates to notifying the public of the project is marketing. The FHWA has indicated that the process of notifying the public and media are part of the project management framework distributed to its project managers (FHWA 2009a). Marketing should be a focus during the preplanning of a project, and a variety of methods should be analyzed and used for effective communication of the project status to stakeholders (Sorel 2004a).

Depending on the location, another problem identified is that of cultural differences in the local area. Communicating and managing in diverse cultures requires the project manager to be adept in handling multiethnic and multicultural teams (Miller et al. 2000). Project managers should always be mindful of and perform rigorous research on cultural differences when working on projects abroad (Gray and Larson 2008). When working across borders and in different cultures in Europe, acceptance of cultural variations and understanding differences requires different planning techniques (Hertogh et al. 2008).

Another local issue that can affect a project is the ability of the local workforce to perform required construction activities. As defined in Chapter 2, the local-workforce factor refers to the ability of the workforce, not its availability. As shown in Table A.4, no literature was found that identifies the local workforce as an issue.

Utility relocations and adjustments for projects are common and can have an impact on delays associated with the project. Very complex utility adjustments can cause major project delays, and project managers need to identify preferable strategies for utility coordination (Chou et al. 2009). Project managers need to analyze specific data and information on utility conflicts among utility accommodation stakeholders and identify the needs for managing utility conflicts that occur during the project (Kraus et al. 2008).

Resource Availability

As mentioned in an earlier section, environmental review agencies lack the proper resources (GAO 2008). The workforce is one type of resource that affects the coordination of planning transportation projects.

On a broader scale, research in Europe has found that even though focus was given to developing project team management skills, the training was not sufficient for project team members (Hertogh et al. 2008).

Another type of resource is construction laborers and unions. For an expressway demolition project in Canada, one issue that delayed it was concrete strikes (Crichton and Llewellyn-Thomas 2003). Material delivery and equipment are also resources that must be controlled and that have the potential to delay projects (Lee et al. 2002).

Environmental Conditions

With the increased focus on sustainable materials, project managers now must decide the best course of action for using products not historically used for transportation construction. A multitude of different renewable options that take advantage of recycled materials are available, and the need for these materials should be specified (El-Assaly and Ellis 2000). Environmental degradation has become an issue, and evaluating sustainable options helps limit the impact on the environment (TAC 2009).

The environment provides numerous limitations that must be coordinated and planned around. Each project contains different external environmental factors that can control decisions made throughout the project. 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). Methods for integrating transportation planning with environmental limitations need to be assessed, and studies should determine the feasibility between the two aspects (McLeod 1996). Environmental impacts of the project should be identified and mitigated accordingly (FTA 2003).

Legal and Legislative Requirements

European research has identified that changes in legislation and obtaining the proper legal consents have the ability to influence the progression of a project and need to be adequately planned for. Legislative procedures and project consents were found to be key causes of major scope increases (Hertogh et al. 2008).

The FTA guidelines for project management state that all legal procedures and laws need to be understood so that the planning team understands what decisions they are allowed to make (FTA 2003). As mentioned within the local issues category of this section, the Tennessee DOT has pinpointed that land acquisition legislation can create barriers to procuring the required land (Brown and Marston 1999).

Furthermore, with the influx of alternative delivery methods for transportation projects, procedural law may affect the owner's ability to use nontraditional contract structures. In addition, it appears that the procedural law literature pertaining to alternative delivery methods and how they affect the complexities of projects is relatively scarce. When discussing legal obstacles to alternative delivery methods, one could assume that either the local governing body allows alternative delivery methods or it does not.

Along with the legal options available for alternative delivery methods is the willingness and ability of local firms that can participate in alternative delivery transportation projects. In particular, the perception of design-build (DB) is that the roles of the public engineering workforce will change; this view is a significant barrier to implementing DB in states without previous DB experience (Gransberg and Molenaar 2008). As shown in Table A.4, this article is the only research pertaining to local acceptance of alternative delivery methods.

Global and National Conditions

Another area to consider for transportation projects is the effect of global and national issues. The global economy should be considered when project managers are planning construction projects (Gray and Larson 2008). A Florida DOT workshop found that the global increase in fuel and steel costs adversely affected the bidding market. The increase was probably due to availability or incidents driving up the costs; however, the research did not specify what was responsible for the increases.

The increase in costs would contribute to the resource availability category discussed previously, but because it occurred on a global scale, it is also classified within this category. As shown in Table A.4, the literature referring to global and national factors is limited, with the exception of the referenced research.

Unusual Conditions

The last category under the context dimension is unusual conditions. Unusual conditions have the possibility of affecting transportation projects but are difficult to plan for proactively.

As described in Chapter 2, weather refers to conditions unusual to the area where the project is located. A bridge demolition project in Canada states that unexpected weather in the form of an unusually wet season affected the plan, and the course of construction had to be altered retroactively (Martin and Does 2005). A Florida DOT study also found that a force majeure event (e.g., a hurricane) disrupted petroleum supplies and affected the number of bidders (Casavant et al. 2007).

Besides the above-mentioned articles, research appears to be deficient in regard to unusual conditions, such as abnormal weather and force majeure events.

Financing Dimension

The important factor to remember in complex-project management is that each of these methods comes with its own set of rules and constraints, which could have a marked impact on project performance (Dooley 2009).

Process

The issues that surround the financing of complex rapid renewal projects are primarily legislative. A public agency must gain permission from its government to implement a new method of obligating that government for the cost of a capital improvement. This makes the process susceptible to political pressure from interest groups having a stake in maintaining the status quo (Gilbert and Krieger 2009).

The controversy and distrust that was manifested with the implementation of DB contracting in transportation 20 years ago is a great example of the primary issue that must be solved before innovative financing can truly become innovative (Little 2006, Price 2002).

Because of the traditional blending of federal and state funds to pay for infrastructure, legislative remedies need to be authorized in every state and will probably work their way down to local entities. This creates an issue in regard to uniformity of authority from state to state (Gilbert and Krieger 2009). No easy solution exists for this situation. One can point to the diversity of alternative project delivery legislation across the country (FHWA 2006) to realize the enormity of this undertaking. One possible approach would be for the federal government to take the lead and tie access to federal-aid funding to the use of innovative financing.

The transition of financing has reversed the initial scoping stage of projects. Traditional three-dimensional project management assumes that once the cost of the project is known, financing can be obtained from public coffers. Thus, the scope of work is defined largely by the technical requirements of the project, and project designers work on the principle that the agency will have to find the money to fund the project and that the design itself will define the project budget and schedule.

Complex projects tend to work in reverse of that principle or thinking. For many projects, the financing must be arranged in conjunction with the design process (Persad et al. 2008). Therefore, the focus shifts from how much money is needed to deliver the desired capacity to how much capacity can be delivered for the available financing.

Although it can be argued that all infrastructure projects must be delivered within a budget, the sequence of when the budget is established in relation to the project's scope of work is different for complex projects. Routine projects establish the scope of work, request the funding, and then adjust the scope to fit the funds. Complex projects often must set the budget at a very early stage and then literally develop the detailed scope of work within the constraints set by available financing (Heiligenstein 2009). Thus, the transition is that complex-project managers must begin with a finite sense of budget awareness, and the financing drives the project scope.

The other major process issue is the training of project managers to have the necessary financial acumen to be able to implement these new and sometimes exotic means to deliver rapid renewal projects. The project managers will not have to obtain MBAs, but they will need to be able to understand the causal relationships associated with each new finance method (Persad et al. 2008).

This understanding can be a tall barrier for implementation when one considers that the transportation industry is dominated and led by engineers. The current engineering education system furnishes little, if any, instruction on financial analysis or the business side of engineering (Russell et al. 2009).

Therefore, to implement these new methods involves training and education at two levels. The first target for education is the current group of complex-project managers, and the effort will necessarily consist of development and delivery of continuing education courses that are designed to impart the requisite knowledge to the adult learner who has no background in the subject. The second target for education needs to focus on U.S. universities and to develop consensus on how much finance education is necessary for the next generation of complex-project managers (Chinowsky 2002).

Public

For the public financing category, Title 23, Section 106(h) applies and requires an annual project financial plan to qualify for federal aid (FHWA 2007a). The major issues with public funding are related generally to ensuring that sufficient funding is available at the state level to qualify for the federal-aid match.

Public financing comprises two major parts. The first part is a negative cash flow required for planning, designing, and constructing. This must be followed by a positive cash flow from some source, such as tax revenue, user fees, or tolls, to replenish funds expended by the public agency (Persad et al. 2008). Traditional project management looks at this process in reverse with the positive cash flow occurring first. Financially complex projects often must generate their own funding to service the debt incurred by the capital improvement (Heiligenstein 2009).

The second source of funding comes directly from the states. They can and do collect taxes and fees from motor vehicle users, which are then used to support transportation projects. States usually retain more flexibility in the varieties of their tax revenues and in their ability to legally expend those tax revenues (Heiligenstein 2009).

However, the major issue is that taxes imposed by states and localities are collected and administered by various agencies, departments, and offices, and depending on how a particular tax or fee is structured or designated in state and local law, a constraint on its use is created. Thus, managers of complex projects need to have more than just a budget. They need to have a financial plan that clearly articulates the allowable usage for every source of funding. These constraints may alter the way the project is designed to ensure that construction packages line up with the sources of their funding.

The major state transportation taxes are motor fuels taxes and fees, motor vehicle registration fees, and motor vehicle sales taxes. The issue here is the political sensitivity to these very visible taxes and fees (Chouinard and Perloff 2007). These taxes can be raised, lowered, or eliminated in a state legislature without regard to the fact that many infrastructure project financial plans rely on revenue forecasts from this source.

Currently, state funding furnishes roughly 43% of total surface transportation funding in the country, and the federal share equals nearly 21% of the local share, which runs around 36% (Heiligenstein 2009). This makes managing public financing critical for a project's chances of being built.

Bond Financing

Bond financing is another traditional funding mechanism. The issues with this source of funding are summarized nicely by a report from Texas (Persad et al. 2008):

> Investment banks require a projected annual revenue/expense ratio of 1.25 to 1.30 to consider a project as viable and for it to earn a AAA [highest possible] bond rating. Weaker bond ratings force up the lending interest rate, while tax-exempt bonds attract favorable lower rates. To hedge against low revenue in the early years, bond companies often require a reserve fund of 20–25% of the bond amount. Guaranteeing to cover bond payments or expenses can reduce the amount borrowed. For example, the TxDOT will cover maintenance costs for SH 130 of approximately $800 million over 35 years.
>
> Borrowing is initially more expensive to the public sector than traditional financing because of administrative and legal costs coupled with debt issue costs and interest payments, as well as the profit margin required by investors. Moreover, if the contractors are aware of the revenue estimates for the project, they may bid up to that level. The public sector must have a competitive bidding process and must establish a set of tools for evaluating bids.

Borrowing Against Future Funding

Borrowing against future funding financing recognizes the fact that when the federal government has available funding for a federally approved project and the state does not have the required funding to qualify for a match, the project dies until the state can find the money. Thus, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the National Highway System Designation Act of 1995, and the Transportation Equity Act for the 21st Century (TEA-21) of

1995 were enacted to create financial mechanisms to deliver much-needed infrastructure projects (FHWA 2002).

The fundamental logic behind these instruments is the idea that if a project is delayed, its cost escalates with the market. Therefore, if the project can be paid for with currently available federal funds, the long-term result is a benefit to the government.

These bills created State Infrastructure Banks capitalized with federal funds, GARVEE bonds that permit states to borrow their share in anticipation of future federal grants, and Transportation Infrastructure Finance and Innovation Act (TIFIA) loans that can be used for major projects of national significance (FHWA 2002). The major issue is that the state is essentially mortgaging its access to future federal aid when it uses these innovative financing alternatives.

An interesting twist to federal-aid funding is a concept called "advance construction." Advance construction

> 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. A variation is partial conversion of advance construction where a State may elect to obligate funds for an advance-constructed project in stages. (FHWA 2002)

The project management issues here involve packaging the project's major work features in a manner that allows them to be separately identified and funded. This method also involves the potential reduction of future state funding for other projects by expending those funds today (Resource Systems Group 2007).

Revenue Stream

All of the specific methods under this type of financing revolve around the idea that the transportation asset can in fact furnish a service for which the traveling public is willing to pay. That value can be converted to cash by charging tolls or fees.

Many of these projects are funded by bonds issued against the future revenue's ability to adequately service the debt. Therefore, the cost estimate used to determine the size of the bond issue is generated at a very early stage in project development, making the development of appropriate contingencies for cost escalation difficult (Touran 2006).

Revenue stream financing also creates a fixed schedule for the project delivery process because the debt instruments require service starting on the date specified in the bond. This requires that a project manager must design to an unreplenishable budget within a time frame fixed, not by the technical demands of the project, but rather by the strictures imposed by the financing.

Revenue Generation

The revenue generation issue deals with ensuring that the postconstruction revenues are sufficient to cover not only the debt but also the operation and maintenance costs of the facility (Harder 2009). Revenue generation financing also drives design decisions for those features of work, such as pavements, that could jeopardize the financial plan if they fail prematurely or require more maintenance or rehabilitation to service the traffic demand placed on the road.

In addition, the amount of revenue is related directly to the amount of traffic that uses the facility. Thus, estimates of traffic growth must be realized to generate sufficient revenue to retire the debt as planned (Persad et al. 2008). Once again, the financing drives the decisions made during planning and design, possibly increasing the amount of resources and effort expended to select those design assumptions instead of those of a traditional project.

Vehicle Miles Traveled Fees

The primary issue with revenue generation from vehicle miles traveled (VMT) is the ability of the state to measure the number of miles traveled so it can assess the appropriate fee for each traveler.

Cordon and Congestion Pricing

Cordon and congestion forms of revenue generation also have the added benefit of redistributing traffic patterns away from congested areas by making it costlier to use them than other facilities. The major issue will be dealing with the political backlash from disgruntled road users and the business community, whose traffic will drop. This issue will be particularly acute for cordon pricing, in which the cost of deliveries, taxis, worker commutes, and so on will skyrocket as a result of the daily requirement to enter the cordon zone (Kirby 2007).

Asset Value

Monetization of Existing Transportation Assets

The viewing of public assets as instruments that can be rented to the private sector is a paradigm shift in a governmental culture that views most infrastructure as a sunk cost with a continuing need for investing in operations and maintenance. One author explains this issue as follows:

> A great deal of attention has been paid to a small but growing number of recent cases in which revenue-generating publicly owned transportation assets have been leased to private-sector initiatives for very long time periods in exchange for substantial up-front payments. Pension funds and other private investment

> funds are showing increasing interest in the long-run, low risk, reliable cash flow of revenue-generating transportation infrastructure. (Kirby 2007)

Therefore, this shift seems promising, but the issue of identifying the standard to which a public highway must be maintained can halt a project (Harder 2009). In addition, the perception that leasing out tax-funded capital improvements constitutes a violation of the public trust must also be overcome.

Leasing out tax-funded capital improvements goes against the traditional usage of public facilities and the idea that the government is not a profit-making entity. The FHWA (2009c) defines the remaining issues as follows:

- Potential undervaluation of an asset to be leased;
- Loss of public control over toll rates;
- Loss of public-sector revenue streams;
- Potentially burdensome toll increases;
- Inequitable return on private-sector equity; and
- Channeling toll proceeds away from transportation purposes.

Franchising

Franchising is being used to finance transportation improvements such as intelligent transportation systems or public wireless communication systems in transportation corridors:

> Traditionally, franchising involved the granting of access to public right-of-way or other public facilities in return for the rendering of specified services to the public. Franchising historically was applied to natural monopolies where it was uneconomical or disruptive to permit more than one private provider of service to operate the service. (Orski 1999)

All of the issues for monetization apply to franchising, albeit at a lower monetary level. Franchising is usually done on a smaller scale and therefore will not generate the same level of potential political opposition. However, the state must still assess the risk of the franchisee leaving the concession prematurely.

In addition, the contract with the franchisee will be a new type of instrument with which the public contracting officials may be unfamiliar (Verhoef 2007). "Most franchise agreements stipulate a return on investment that is often based on an assumed rate of growth. Therefore, the final issue is developing remedies for the agreement if growth rates are not realized" (Orski 1999).

Carbon Credit Sales

The most exotic form of asset value financing is the sale of carbon credit sales [Mountain Association for Community Economic Development (MACED) 2008] associated with a given project to finance its construction. Carbon credits are created as follows:

> Carbon sequestration [is] a process through which atmospheric carbon dioxide is absorbed by trees, plants, and crops through photosynthesis and stored (or sequestered) as carbon in biomass (tree trunks, branches, foliage, and roots) and in soils. The carbon stored by trees has a market value because corporations seeking to offset their carbon output can purchase carbon offset credits on an international market. (MACED 2008)

The carbon credit market is regulated by the Chicago Climate Exchange (CCX), which functions as a "stock market-type clearinghouse that brings carbon credit buyers and sellers together in a marketplace" (MACED 2008). The CCX is responsible for setting rules for emissions credit programs. It also monitors compliance with the program regulations and acts as the control mechanism that regulates the buying and selling of credits.

No instances of the use of this method were found in the DOT arena; however, local transportation authorities have been using it for years. Essentially, the public entity pledges to protect a forested area or greenbelt and gets the CCX to securitize that obligation. Then, industries that are heavy emission producers buy those credits to offset their processes and bring them into compliance with environmental policy.

Carbon credit sales financing would seem to be easy to implement if the political context issues could be overcome. The public perception issues discussed previously also apply here. In addition, the pledge to not develop those assets that are credited for carbon sequestration could reduce an agency's ability to meet expanding demand requirements with added capacity on existing ROW. The final issue is that the theory of carbon credit sales is controversial in and of itself (Fulton and Vercammen 2009).

Project Delivery Methods

PPPs are the most well known project delivery methods. Their projects are often tolling facilities. Concessions and comprehensive development agreements are specific forms of PPPs (Heiligenstein 2009).

The Trans-Texas Corridor project is a good example of finance-driven project delivery (Heiligenstein 2009). In these projects, the government often acts as a type of guarantor for the developer when it approaches the bond market to secure the necessary funds. Vining and Boardman (2008) developed a consolidated list of PPP issues:

- *Separating the analysis, evaluation, contracting, and oversight entities.* Each of these entities has a specific purpose with regard to the supervision of the PPP execution. Thus, putting too many of these responsibilities under a single entity may create a conflict of interest.

- *Ensuring that the procurement process is "reasonably competitive."* The size of most PPP projects is so great that it may be impossible to obtain a truly competitive pricing structure.
- *Preventing the private-sector concessionaire from selling the contract too early.* A PPP becomes an asset with value and, if profitable, could be sold at a profit if the agreement does not address this issue.

Risk

The final category, risk, is not really a financing method but is instead a set of tools that can be used to mitigate the risk of cost overruns and failure to achieve the necessary fiscal requirements that define a successful project. At this writing, two techniques have been found in the literature.

The first is commodity-based hedging against construction material price escalation (Courteau et al. 2007). Essentially, in a complex project, a series of steps would be taken early in the project development process to address price escalation. The first would be to evaluate various potential design options in the context of price volatility rather than estimated retail cost. Thus, a project that includes a large amount of one material that could be technically substituted for another material would compare the volatility of those two materials and make the design decision to use the less-volatile material if the cost was within reason.

For instance, electrical conductor cable for a roadway lighting system could be manufactured from either copper or aluminum. Selecting the less-volatile commodity reduces the escalation risk that must be accounted for by contingencies. The agency has two other options in this scenario. The agency could plan to incorporate an escalation clause in the solicitation documents to share the risk with its contractors, but that leaves the agency with a future need to find additional funds if the commodity prices rise. The second option is to "purchase enough forward contracts or futures with the proper duration . . . so that [the agency] can cash in the contracts at expiration and use the profits made to cover the losses on the contract and transaction fees" (Courteau et al. 2007).

However, this is not without cost. Transaction fees usually run around 1%. The issue here is the level of risk taken in the financial marketplace by a public entity. Many taxpayers may abhor the idea that a public agency is putting tax monies at risk in the fickle commodities market. Thus, the process should be transparent and well publicized.

The second technique is allowing companies from other countries to compete for and win infrastructure projects, which brings new blood to the project and may allow the agency to accrue a benefit from a different set of business model standards. An American contractor or developer might find a given project too risky, whereas a developer from another country where the average level of project risk is much higher than in the United States would find the same project attractive.

For example, a company from a region of the world where hyperinflation is endemic to the construction industry and the government is struggling to meet its obligations might find a U.S. project, with inflation of 3% to 9%, a pretty tame market, especially given that the U.S. government can be trusted to pay its bills.

Moreover, the U.S. dollar is much less volatile than many of the currencies in the world, which would further reduce the risk to an international venture (Brown et al. 2009). The major issue is allowing foreign contractors to compete for U.S. projects.

Defining the national impact of a foreign entity controlling an asset that is vital to the U.S. economy is crucial. In addition, the benchmark used by international firms will be different from that used by U.S. contractors because of differential inflation and currency exchange rates.

Finally, the issue of local participation must also be addressed when diversifying a project's financing through global participation (Mathur and van Aalst 2009).

Conclusions

It seems intuitive that some factors of complexity are present on virtually all projects and that well-developed, effective practices have been employed as responses to those sources of complexity. One goal of the next phase of this research was to avoid expending resources unnecessarily in the case study task by examining relatively well-understood factors of complexity for which the industry has developed adequate response mechanisms.

Excellent direction in this regard was provided in *NCHRP Web-Only Document 137: Guidance for Transportation Project Management* (Jacobs Engineering Group et al. 2009), which provides an effective basis for current project management theory.

Jacobs Engineering Group et al. (2009) divide the project management process into two kinds of knowledge. The first represents universal elements, involving activities that should occur on all types of projects and across all project life-cycle phases. The second is called "project management by phase" and focuses on project management activities that occur within discrete phases of a project's life cycle.

Table 3.1 shows universal elements, and Table 3.2 shows project phase elements. For each element, the project management activity has been mapped into the 5DPM structure described in this report.

Table 3.1. Universal Elements of Project Management Categorized by 5DPM

Universal Elements	Cost	Schedule	Technical	Financing	Context
Project start-up for all phases			X		
Consultant selection and negotiations			X		
Developing the consultant's cost/fee	X				
Scheduling techniques to ensure adequate time and quality		X			
Milestone and bar charts		X			
Critical path method		X			
Managing project budget	X				
Managing project quality			X		
Quality assurance			X		
Quality control			X		
Ensuring the performance of consultants			X		
Managing risks and creating a risk management plan	X	X	X		
Managing critical path items		X			
Agency coordination delays		X	X		
Political delays					X
Right-of-way			X		X
Utilities			X		X
Project change management			X		
Preparing for project closeout		X	X		
Project closeout		X	X		
Project audits	X	X			

Source: Adapted from Jacobs Engineering Group et al. 2009.

It can be seen from these tables that no elements of this very comprehensive study involve financing. This leads to the inference that the authors assumed that financing would not affect the management of a typical project. In other words, then-current project management theory assumed that financing will be available in sufficient amounts and in sufficient time to facilitate the delivery of the project.

This assumption has never been truly correct in that many projects exceed their initial budgets during the construction phase. Complex projects often have much greater cost uncertainty than do noncomplex projects (Touran and Lopez 2006). Thus, the aspect of when and how much financing is available can literally translate to conservative design decisions to deliberately restrict the scope of work to minimum functional requirements as a means of reducing the risk that the cost of the project will exceed its available funding. In fact, this risk is one that leads to the delivery of critically needed infrastructure by using PPP (Klijn et al. 2008), as noted in the following quote:

> In a PPP concession, the design, building, financing, and commercial operation of an infrastructure project (such as a road or a building such as a school) are integrated into a contract. The added value lies in the lower cost of coordination between the various components (often expressed as efficiency or value for money gains). (Klijn et al. 2008)

Tables 3.1 and 3.2 outline several tools that have been developed to aid project managers in managing projects. The literature review validates the need to add the dimensions of context and financing to the complex-project management model, because in both cases, these dimensions can and do have a direct impact on the final design, cost, and schedule of projects.

As seen in Tables 3.1 and 3.2, no tools were identified for financing, and few universal tools for managing context that cut across all project phases were mentioned, indicating that many contextual factors are project specific.

The information in these tables further verifies that context and financing need to be addressed proactively in project development. The goal of Phase 2 of this research, as described in the following chapters of this report, was to use case study methodology to identify additional complexity factors, understand the interaction between complexity factors, and determine the effectiveness of response mechanisms available for project managers to better manage these complex projects.

Table 3.2. Project Management by Phase Categorized by 5DPM

Project Management by Phase	Cost	Schedule	Technical	Financing	Context
Planning phase					X
Internal and external agency coordination					X
Interagency Review (IAR) meetings					X
Agency concurrence at milestones					X
Public involvement plan					X
Informing and involving elected officials					X
Involving customers (stakeholders, community, and business owners)					X
Draft and final environmental document			X		X
National Environmental Policy Act			X		X
State and federal regulations and streamlining processes					X
Reviews and concurrences			X		
Design phase			X		
Design activities			X		
Preliminary engineering			X		
Final design review			X		
Plans, specifications, and estimates	X		X		
Agreements process					X
Permits and final approvals					X
Advertisement					X
Bid opening	X				X
Awarding the contract	X	X	X		
Redline revisions			X		

Source: Adapted from Jacobs Engineering Group et al. 2009.

CHAPTER 4

Development of Case Studies

The R10 project's Task 4 was to develop and conduct case studies. Case studies can be used to look in depth at projects to focus on attitudes, behaviors, meanings, and experiences by obtaining information from a number of different sources related to a project.

For the R10 project, a series of in-depth case studies was conducted to build on the literature review identifying the five dimensions of project management. These case studies would help to find tools to use in managing complex projects and to supplement the knowledge framework created previously.

Case study research in construction has encountered much criticism, for such characteristics as small sample size and unwarranted generalization of results, lack of trust of participants, and lack of rigor of protocol. To address these criticisms, the research team used a variety of methods, which included using different sources of information, maintaining a chain of evidence, and searching for patterns among the data through data coding.

Fundamental observations were sought initially, but often key variables emerge during data collection and analysis. Thus, the final plan included flexibility to change form and format as unexpected findings developed, which allowed the researchers to exploit those opportunities.

Through the analysis and conclusions of this process, explanations were formed to tie conclusions with assembled data to validate the research and its findings (confirmed by previous results by Taylor et al. 2009 and Yin 2002). The analysis was conducted on the three levels shown in Table 4.1.

Level 1

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

The research team then conducted an interview with Carl Gottschall, the FHWA major projects team leader, in an effort to reduce the number of possible projects (Appendix B). Following this interview, the team evaluated the size, type, level of success, location, and current phase of each project and determined that a variety in each of these areas was desirable. The team also presented the possible projects to the SHRP 2 R10 panel for their input.

On the basis of all this information, the team identified 15 projects in the United States to use as case studies. Later, during the process of setting up the interviews, one of the originally identified projects withdrew from consideration and was replaced by another project.

The projects identified are geographically dispersed (Figure 4.1) and represent different types of agencies in different climates and with other conditions. Similar discussions occurred for identification of the international case study projects.

In addition to being dispersed geographically, the choices represent a number of different types of projects (Table 4.2).

The case study projects were also in different phases of development. Some projects, such as the Detroit River Bridge, were still in planning; others, such as the Lewis and Clark Bridge, were complete; while others, such as the Doyle Drive project, were somewhere in between.

Level 2

The second level of analysis was to obtain documents and reports for each of the identified case study projects. These documents were obtained before, during, and after the interviews and served several purposes.

The main reason for these documents was to prepare for the interview and obtain a base understanding about the

Table 4.1. Summary of Case Study Methodology

Level	Description
1	Select complex projects of different sizes, in different countries, with different reasons for complexity, and at different levels of success, as identified in the literature review and in discussions with people knowledgeable of the industry.
2	Obtain published reports of complex case study projects from the highway, airport, and transit sectors.
3	Interview public transportation agency personnel, contractors, and consultants with complex-project management experience.

project. These documents also helped identify tools and indicated the actual implementation of the tools. Some of the documents represented tools in themselves, such as risk management plans and public involvement plans.

Level 3

The primary input to the case studies was gathered through a Level 3 analysis of structured interviews with agency personnel, contractors, and consultants who have been part of teams

Table 4.2. Summary of Case Study Project Types

	Corridor	Bridge	Bridge and Corridor	Tunnel and Bridge or Roadway	Transit
No. of Cases	7	4	3	2	2

involved with the identified projects. The structured interview outlines were developed by a method similar to that prescribed by the U.S. Government Accountability Office (GAO 1991).

The GAO method states that structured interviews can be used when information must be obtained from program participants or members of a comparison group or when essentially the same information must be obtained from numerous people for a multiple case-study evaluation (GAO 1991). Both of these conditions applied to this project. Therefore, the tool was deemed appropriate for the research.

The process involved developing a questionnaire that was made available to each interviewee before the interview, collecting responses in the same order, and using the same questions for each interviewee. The final questionnaire is shown in Appendix D.

Figure 4.1. Location of case study projects in the United States.

The information can be gathered by both face-to-face and telephone interviews. Adequate time is given by the GAO method to ensure that the interviewee understands each question and that the data collector understands the answer. In addition, interviewees are allowed to digress as desired, which allows the researchers to collect potentially valuable information that was not originally contemplated. The output is used to present the agency perspective on various points analyzed in the subsequent tasks.

In addition to gathering data about the issues and tools on the project through the personal interviews, key project personnel were asked to rate the complexity on each of the five dimensions. The responses were indexed to create a complexity map for each project. A sample complexity map is shown in Figure 4.2 for a hypothetical project with extremely complicated schedule, financing, and context issues and with moderate cost and technical complexity.

Once the questionnaire was developed and pilot tested, the team held a telephone-based training session. Each member of the team was to conduct at least one case study interview. One way to ensure consistency in the data collection was through developing the questionnaire, and another was to conduct the training.

This training was a 2-h presentation of the questionnaire, a demonstration of the interview technique, and a discussion of the documentation for reporting on the project.

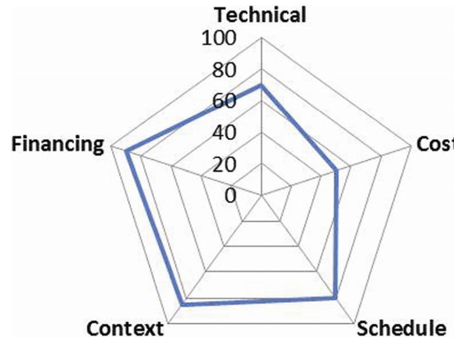


Figure 4.2. Sample complexity map for a hypothetical project.

Throughout the training, team members were encouraged to ask questions and have discussions.

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

CHAPTER 5

Analysis of Case Studies

The R10 project's Task 5 was to analyze case studies. The documentation and analysis of the case studies enabled the research team to identify critical success factors for each case. A detailed case study report is available at www.trb.org/Main/Blurbs/167481.aspx, and a summary of each case study is provided in the R10 guide.

The analysis included integrating the knowledge acquired from the case studies into the knowledge framework developed during the literature review (created during Phase 1). The goal was to find the critical project management practices or strategies that led to success on the case study projects.

To facilitate the analysis, a table of the projects and the identified methods and tools was developed. This table has undergone several iterations to categorize the methods and tools into similar categories.

The primary objective of the case study data collection and analysis was to identify methods and tools that can be implemented to manage complex transportation projects effectively. The team identified five project development methods (Table 5.1) and 13 tools (Table 5.2) that were in a plurality of the 18 cases studied.

The project development methods are typically implemented at an executive level and need to be started at the very beginning of project development. Many of these methods serve as a basis for decisions that need to be made throughout the project life cycle.

The tools, however, are typically used later in the project life cycle during execution of the project. However, tools can be started in the planning stage and continue through design and construction of the project.

Table 5.3 summarizes the findings of the case studies and relates the methods and tools back to 5DPM. Brief summary lists for these methods and tools also follow in this chapter. More-detailed explanations and keys to effective use of these tools are described in the guide and training series.

The training materials are available online at www.trb.org/Publications/Blurbs/167482.aspx.

In a count of the number of times the methods and tools are used in the case study projects (Table 5.3), it can be seen that a majority of the methods and tools are used in many of the case study projects.

The methods and tools that were identified also represent each of the five dimensions, which confirms the migration of complex-project management from three to five dimensions. Each of the methods and tools identified has specific implementation techniques that were found through the case studies.

Project Development Methods

The project team identified five project development methods that were used in the majority of the complex projects to effectively manage overarching degrees of complexity that were not attributable to one specific dimension of complexity during the execution phase. Key points for each project development method follow.

Define Critical Project Success Factors by Dimension (as Required)

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

Table 5.1. Project Development Methods Identified by Case Study Projects

	Project								Project									
Development Method (Executive Level)	**Capital Beltway**	**Detroit River Inter-national Crossing**	**Doyle Drive**	**Green Street**	**Heathrow T5**	**Hudson-Bergen Light Rail Minimum Operable Segment**	**I-40 Crosstown**	**I-95 New Haven Harbor Crossing Corridor Improvement Program**	**I-595 Corridor**	**Inter County Connector**	**James River Bridge/ I-95 Richmond**	**Lewis and Clark Bridge**	**Louisville Southern Indiana Ohio River Bridge**	**New Mississippi River Bridge**	**North Carolina Tollway**	**Northern Gateway Toll Road**	**T-REX SE I-25/ I-225**	**TX SH-161**
Define critical project success factors by each dimension, as required	X		X	X	X		X	X	X	X	X	X		X	X	X	X	X
Assemble project team	X	X	X	X	X		X	X	X	X	X			X	X	X	X	X
Select project arrangements	X	X	X	X	X				X		X	X		X	X	X	X	X
Prepare early cost model and finance plan	X		X	X			X	X	X	X				X	X	X	X	
Develop project action plans to address resource issues	X	X	X				X		X		X		X	X	X	X	X	X

Table 5.2. Project Execution Tools Identified by Case Study Projects

	Project								Project									
Tool (Project Team)	**Capital Beltway**	**Detroit River Inter-national Crossing**	**Doyle Drive**	**Green Street**	**Heathrow T5**	**Hudson-Bergen Light Rail Minimum Operable Segment**	**I-40 Crosstown**	**I-95 New Haven Harbor Crossing Corridor Improvement Program**	**I-595 Corridor**	**Inter County Connector**	**James River Bridge/ I-95 Richmond**	**Lewis and Clark Bridge**	**Louisville Southern Indiana Ohio River Bridge**	**New Mississippi River Bridge**	**North Carolina Tollway**	**Northern Gateway Toll Road**	**T-REX SE I-25/ I-225**	**TX SH-161**
Incentivize critical project outcomes	X		X		X				X	X	X	X		X	X	X	X	X
Develop dispute resolution plan	X	X	X	X					X	X	X	X				X	X	
Perform comprehensive risk analysis	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Identify critical permit issues	X	X	X		X		X		X	X	X	X	X	X	X	X	X	X
Evaluate applications of off-site fabrication					X		X				X	X					X	
Determine required level of involvement in right-of-way and utilities	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X
Determine work package and sequence			X	X			X		X	X	X	X	X	X		X	X	
Design to budget														X		X	X	
Colocate team									X	X				X	X	X	X	
Establish flexible design criteria	X	X		X	X			X	X	X	X	X		X	X	X		X
Evaluate flexible financing	X	X	X			X			X	X				X	X	X	X	X
Develop finance expenditure model	X		X					X	X	X					X	X	X	
Establish public involvement plan	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X

Table 5.3. Identified Methods and Tools by Number of Case Study Projects and Dimensions

Method or Tool	Number of Projects	Dimension
Development Method (Executive Level)		
Define project success factors by each dimension, as required	15	All
Assemble project team	15	Context, Technical
Select project arrangements	13	Technical, Financing, Schedule
Prepare early cost model and finance plan	11	Financing, Cost
Define political action plan	12	Context
Tool (Project Team)		
Incentivize critical project outcomes	12	All
Develop dispute resolution plan	10	All
Perform comprehensive risk analysis	17	All
Identify critical permit issues	15	All
Evaluate applications of off-site fabrication	5	Technical, Schedule, Cost
Determine required level of involvement in ROW and utilities	15	Technical, Context, Cost
Determine work package and sequence	10	Technical, Schedule
Design to budget	3	Technical, Cost
Colocate project team	6	Technical
Establish flexible design criteria	13	Technical
Evaluate flexible financing	11	Financing
Develop finance expenditure model	8	Financing
Establish public involvement plan	16	Context

Assemble Project Team

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

Select Project Arrangements

- Calculate road user costs and translate into cost of schedule delay or acceleration, which can be included in contracting language.
- Calculate cost of capital or other cost-model inputs and include cost-sharing and cost-saving processes such as the alternative technical concept or contingency saving and sharing in contract language.
- Use comprehensive risk analysis and mitigation planning to identify potential sources of delay and cost overruns, which include politically powerful neighborhood groups, unions, local jurisdictions, SHPOs, utilities, social equity and advocacy groups, environmental agencies, and organizations. In addition, work closely within the project team (owner, designer, and contractor) to develop contract language aimed at mutually beneficial outcomes, such as meeting disadvantaged business enterprise (DBE) and project approval ratings goals, minimizing the number of public complaints, environmental incidence reports, and lost-time accidents, and any number of possible project outcomes.
- Recognize the large continuum of contracting and delivery options between formal low cost, open bid award, design-bid-build (DBB) procurement and pure design-build (DB) turnkey contracting. Any procurement or contracting method can be tailored to require prequalification of bidders, legal structure of proposers, or other partner requirements that add value to the project. Reject the "liability of labels" (Jackson 2010) and choose innovative contracting and alternative delivery that meet the needs of the project.

Prepare Early Cost Model and Finance Plan

- Understand available funds and establish scope, budget, and schedule that are viable.
- Use cost models to phase the work to fit funding and cash flow.
- Develop mechanisms for frequent real-time cost and schedule updates to confirm validity of cost models.
- On complex projects, the reality is that the availability of financing and funding determines cost, schedule, and scope decisions, rather than the reverse relationships, which are standard for many agency projects.
- Develop process for early contractor and vendor input using tools such as design-supply-build, construction management at risk, or design-build delivery systems, contractor review boards, and alternative technical concept proposals.
- Implement a process for getting unsolicited proposals into the project or program. Complex projects are aided by innovation, but highly standardized specifications and general requirements stifle innovation. Within reason, consider as many options as possible, even those that may at first appear unconventional.
- Sometimes the process of identifying cost models and financial plans will be steeped in uncertainty and result in unreliable or confusing data, but the process of attempting to model costs is beneficial in identifying risks and establishing realistic contingencies and managing stakeholder expectations. Each complex project should attempt cost modeling, if only to identify high-risk (or high-uncertainty) areas and assign realistic contingencies.

Define Project Action Plans

- Work with legislators on required statutory changes needed to allow for flexibility in contracting and delivery tools so that project procurement can be tailored to fit the needs of complex projects.
- Develop neighborhood councils to facilitate dissemination of information.
- Expand comprehensive risk analysis and management programs to include identification and mitigation of potential political risks.
- Prepare thorough baseline documentation and comparative analyses to better defend project choices from political attacks. Politically motivated challenges can delay projects, and proper documentation and ability to show due diligence and objective decision making are keys to minimizing delays.
- Establish a direct communication link between politically powerful stakeholders and project leaders, agencies, secretaries, or project administrators who can disseminate information reliably and quickly within the project partner organizations.
- Develop working relationship(s) with unions early in the process to facilitate DBE participation goals, schedule control, and so forth. Project labor agreements can be valuable in establishing expectations.

Tools

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

Incentivize Critical Project Outcomes

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

Develop Dispute Resolution Plan

- Negotiate dispute resolution plans for neighborhood groups, U.S. DOT 4(f) signatories, and other indirect stakeholders.
- Integrate dispute resolution plan into a political action plan.
- Contractually stipulate the dispute resolution process between designer and owner should scope agreement issues arise.
- Prepare a memorandum of agreement, which all local jurisdictions are signatory to, that elaborates a process for resolving disputes without increasing cost or schedule risk.
- Work with designers and city and local review agencies on flexible approval processes if new or innovative design solutions are under consideration. Use mechanistic designs and nonstandard protocols to resolve conflicts or disagreements.

Perform Comprehensive Risk Analysis

- Implement risk analysis and mitigation plan at early stages of project. Risk analysis can be both formal and informal, but both must include some clear and concise assignment of responsibilities and assignment of designated resources.

- Use a spreadsheet application for predictive modeling, forecasting, simulation, and optimization to establish contingencies for the project.
- Expand risk analysis to include context and financing issues, such as railroad, utilities, 4(f) issues, National Environmental Policy Act (NEPA) issues, appropriations and capital bill allocation (use it or lose it funding), and effect of delays on private equity viability.
- Use outcomes of risk analysis to develop aggressive mitigation plans, including the possibility of reallocating contingency within project segments or phases to prevent delays or cost increases.
- Bring in contractor group or construction specialty review board early in the project life cycle to offer input on means, methods, and material supply issues.
- Use expert panels and historical records to assign probabilities (qualitative or quantitative) to potential loss events and factor these probabilistic evaluations into prioritization and mitigation strategies.
- Integrate risk analysis and mitigation plan to coincide with critical project success factors. Identify risk events that would potentially prevent goal achievement, and focus mitigation efforts on these potential adverse events.

Identify Critical Permit Issues

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

Evaluate Applications of Off-Site Fabrication

- As site constraints allow, use off-site fabrication as a schedule control technique.
- Work with designers and contractors to develop innovative off-site construction means and methods to minimize road closures, traffic delays, detour lengths, and public disruption (e.g., noise, loss of access).
- Use standardized, replicated designs to the extent possible for noncomplex aspects of the project (e.g., approach spans, retaining walls, overpasses, bridge deck).
- Consider prefabrication for repetitive work reflecting auxiliary functions such as pedestrian walkways, guardrails, and similar ancillary work.

Determine Required Level of Involvement in ROW and Utilities

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

Determine Work Package and Sequence

- Develop scoping documents based on high-certainty funding sources.
- Develop contracting and procurement plan based partially on local contracting capabilities, available work force, bonding issues, and so forth.
- Determine what work will be performed by owner agency forces (e.g., city crews, state highway agency quality and testing crews).
- Develop work sequencing and staging plans based on road closure and detour options, road user costs, local access issues, and so on.
- Break down design segments into the largest possible packages that balance schedule gains from concurrent designs with resource demands created by need for integration between owner and design teams.

Design to Budget

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

Colocation of Project Team

- On multijurisdictional (e.g., bistate) projects, place a dedicated, empowered, representative project team in a common location.
- Depending on the project delivery system used, the colocation strategy can be incorporated for DB partners or the contracting team in later stages.

Establish Flexible Design Criteria

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

- Use mechanistic designs.
- Implement procurement mechanisms that allow designers to work with major material suppliers and vendors early in the project life cycle.
- Use an alternative technical concept procurement.

Evaluate Flexible Financing

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

Develop Finance Expenditure Model

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

Establish Public Involvement Plan

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

Communication and Dissemination Plan

The major project case studies were conducted successfully and resulted in identification of numerous methods and tools as described in the last section. The next tasks of the research plan involved developing a communication and dissemination plan for sharing the information gathered effectively with the broadest possible audience.

The primary means of communication and information dissemination was agreed to consist of a guide and training sessions (developed and delivered in Tasks 6 through 12 of the project). The guide and training describe the effective complex-project management methods and tools and offer practical implementation guidance to facilitate diffusion of these effective practices into transportation organizations at the national, state, regional, and local levels.

CHAPTER 6

Development of the Guide

Philosophy of the Guide

Tasks 6, 7, and 9 of the R10 project were related to development of the guide. The guide is intended to facilitate use of effective strategies for managing complex projects. To help improve the state of the practice, the guide focuses on practical tools and techniques designed to be immediately beneficial to transportation professionals.

The first chapter of the guide describes how the guide relates to the project management dimensions (5DPM) found in complex projects and the association to the project development process. A conceptual understanding of project complexity and the dimension are developed. In addition, a preliminary presentation of the 5DPM process is provided.

The guide then goes on to develop a deeper understanding of the concepts introduced in the first chapter and to engage the reader in development of outcomes based on a complex-project map, the five methods, and 13 tools that are presented. Complexity maps can be used to make rational resource allocations and to guide the team through the five project development methods. The project development methods are structured processes used to select specific tools for inclusion in the project management plan. In each section, specific case examples and additional resources are included. The philosophy of the guide is shown in Figure 6.1.

The objective of the guide is to identify and communicate the critical factors involved in successfully managing complex transportation design and construction projects. One of the key underlying assumptions of this research is that the ability to manage complexity successfully is related directly to the ability to integrate the project team across the entire life cycle. Therefore, the guide includes discussions of when particular project development methods and project management tools should be used.

Using the Guide

The guide is oriented toward problem solving. The most efficient use of the guide was initially intended to first determine if a project is indeed complex according to the demands of the project and to the experience and resources of the agency managing the project. Then, the five project development methods could be used. Next, the project team leaders would determine which of the 13 project management tools are applicable to the complex project in the agency program. It was later recognized that a project did not necessarily need to be defined as "complex" to benefit from consideration or implementation of any of the complex-project management methods or tools presented in the guide. The 5DPM approach was found to be fully scalable to meet the particular needs on any given project.

Additional revisions were made to the guide upon completion of the pilot training and workshops, working with two state departments of transportation to implement the 5DPM framework. The final revisions to the guide by the research team and its editor were threefold as follows:

- aimed to make the guide less academic, which also led to a more task-oriented presentation of the material;
- incorporated additional information and suggestions to potentially help organizations and project management teams with 5DPM implementation; and
- integrated first-version edits of the guide from the SHRP 2 editors.

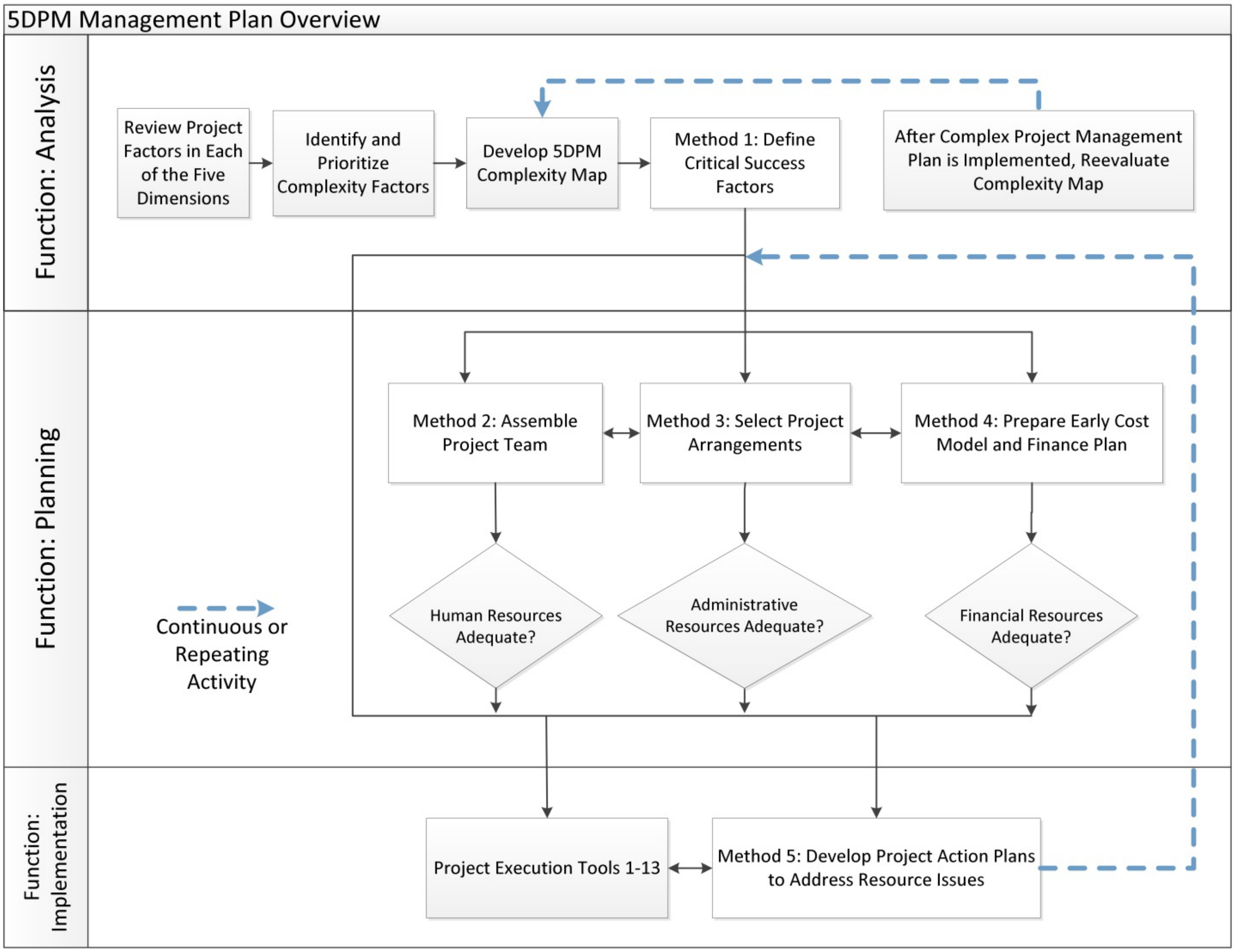


Figure 6.1. Philosophy of the guide.

CHAPTER 7

Pilot Workshops

Task 8 of the R10 research project was to conduct two pilot workshops. In January 2011, the research team set a meeting for early March to work on the training in greater detail. The team also established a meeting room to deliver a very early pilot in Kansas City, Missouri, before the start of the Design-Build Institute of America transportation conference at the end of March.

In February, the team worked on developing the content of the guide and training materials. Specifically, the five project development methods were fleshed out in greater detail as examples of the tools were extracted from the case studies. The team also worked on how to graphically represent some of the information, such as that on the interactions of the project development methods with each other in the project development process and with the tools. This material was incorporated into the guide and the training materials.

In March, the research team continued development of the guide and training materials. On March 28, a pilot training session was held in Kansas City, Missouri. Nine participants were present: four from the Kansas DOT, four from the Missouri DOT, and one consultant, who is a former tollway engineer.

Each of six of the participants had more than 21 years of experience in transportation project management, two had 11 to 15 years, and one had 6 to 10 years. Their job titles were as follows:

- Construction engineer
- Deputy project director
- Field engineer administrator
- Geotechnical engineer
- Project controls manager/right-of-way manager
- Vice president of transportation

The research team presented the first module of the training. This training presents 5DPM and complexity mapping. A presentation was made, and the associated exercise was completed by the participants. The pilot-training participants all seemed very positive about the experience.

At the end of the module, the participants were asked to complete a questionnaire that had Likert-scale responses as well as open-ended responses about their perceptions of the training (Figure 7.1). For these questions, none of the participants had a negative viewpoint (i.e., disagreed or totally disagreed with the statements).

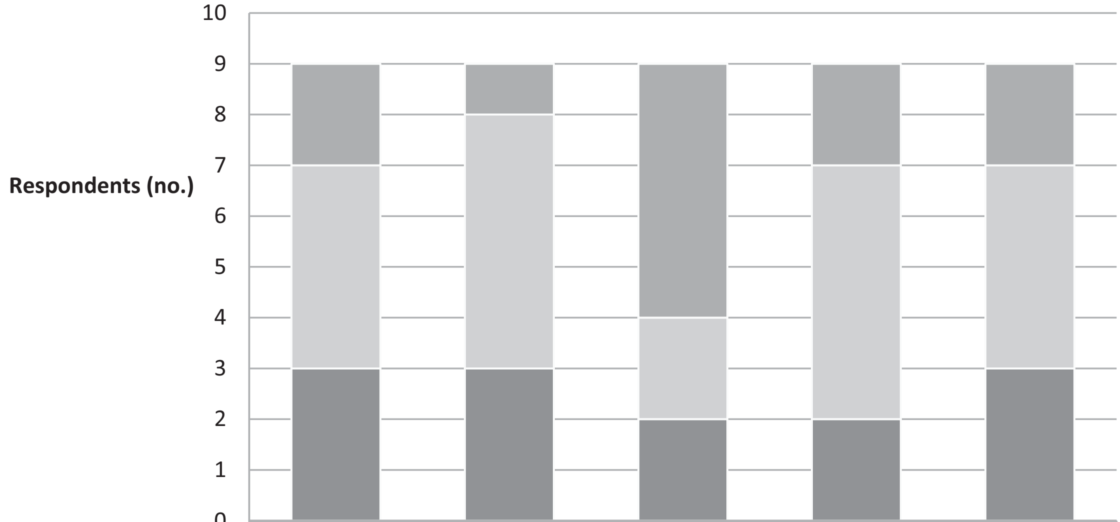
Seven of the participants gave a positive response about the extent to which the training provided valuable information, the exercises were helpful in applying the theory presented, and the training would be recommended to peers. Eight were positive in viewing the training as easy to follow and understand.

The questionnaire also asked respondents about their perceptions of the 5DPM model. Eight participants completed a majority of this section (Figure 7.2). Seven of the eight participants were positive about the extents to which 5DPM advanced the state of project delivery and the context dimension added to project delivery theory.

Six respondents provided a positive response about the extent to which the 5DPM model was applicable to future projects at their DOTs. The remaining respondents on each of these questions neither agreed nor disagreed with the statement. Two respondents disagreed with the statement that the finance dimension adds to project delivery theory.

All participants provided written comments on the training, which were incorporated into subsequent revisions of the training materials. In addition to the written comments on the questionnaire, the research team received the following e-mail message from one of the participants shortly after the training session:

> Just wanted to send you a note thanking you for the opportunity we had yesterday to participate in the pilot training exercise. We really enjoyed the discussion, and practice activity. The majority of the topics really hit home with our history on the



	The module program provided valuable information	The module program was easy to follow and understand	The module program was a good balance between theory and exercises	The exercises were helpful in applying the theory presented	I would recommend the module training to my peers
Totally disagree	0	0	0	0	0
Disagree	0	0	0	0	0
Neither agree nor disagree	2	1	5	2	2
Agree	4	5	2	5	4
Totally agree	3	3	2	2	3

Figure 7.1. Participant perceptions of the training for the Kansas City, Missouri, pilot.

kcICON project. Good luck with your project progress, and hopefully we'll hear more about it in the future. If you ever think we may be of some assistance, or you want to bounce something off of us, don't hesitate to get in touch.

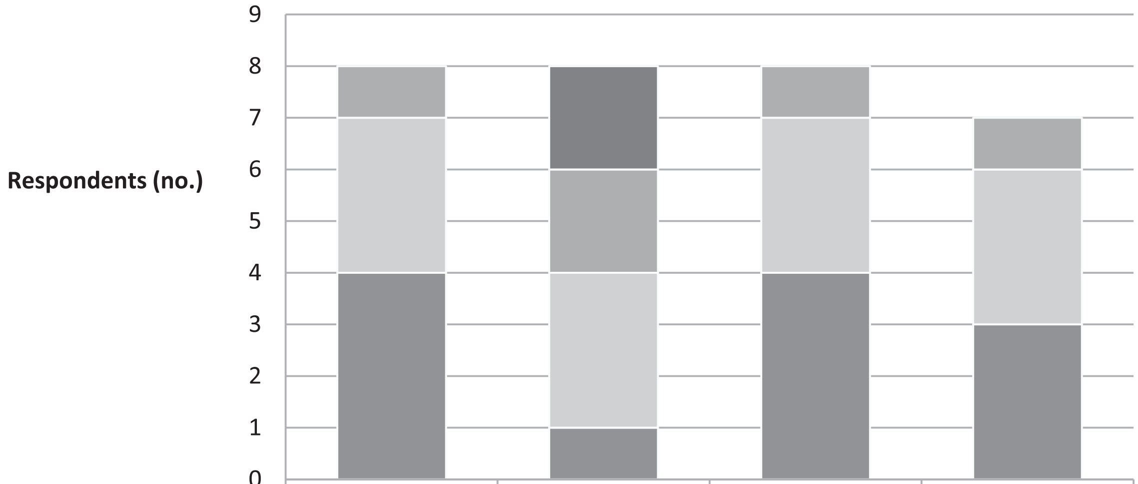
The research team also worked on validation of the 5DPM concept, the project development methods, and the tools. The research team held out two case studies from the original sample to serve as validation cases. The I-74 Corridor project in eastern Iowa and the I-15 South project in Las Vegas, Nevada, were studied using a simplified protocol to assess the validity of the 5DPM model, the project development methods, and the tools.

The validation methodology was adapted from operations research, where it is used to validate process models. In the research team's adaptation, a member of the research team (the "modeler") analyzed public archival data on the project and attempted to predict the complexity map, complexity factors, development methods, and tools for the project.

A project representative (the "expert") was then sent a copy of the project case study interview questionnaire, a glossary of terms, and the complexity assessment and ranking form. The project leaders of the hold-out validation cases were subsequently interviewed in a way similar to that in the original case studies. The scoring, ranking, and mapping of the complexity were compared between the modeler's prediction and the expert's opinion. The actual methods and tools used on the project were also compared to those of the modeler's prediction.

In general, four of the five dimensions appear to be well understood in both cases. Factor identification for the cost, schedule, technical, and context dimensions appears to be captured well in the model. In addition, the model works well in predicting the effective methods and tools appropriate for a complex project.

Finally, it appears that financing is clearly a source of complexity but is currently a challenge to the industry and represents an area that needs further investigation. The project team believes the reason behind the model's inability to predict financing factors has much to do with the evolving funding and finance structures with which the industry is currently working. In other words, it is difficult to develop a predictive framework for an area that is undergoing such rapid innovation and change.



	The 5DPM model advances the state of project delivery	Based on my experience, the finance dimension adds to project delivery theory	Based on my experience, the context dimension adds to project delivery theory	The 5DPM model is applicable to future projects in my DOT
Totally disagree	0	0	0	0
Disagree	0	2	0	0
Neither agree nor disagree	1	2	1	1
Agree	3	3	3	3
Totally agree	4	1	4	3

Figure 7.2. Participant perceptions of 5DPM for the Kansas City, Missouri, pilot.

In April 2011, the research team continued refinement of the guide and training materials, which it submitted to SHRP 2 on April 19 for review. On April 27, the research team traveled to Salt Lake City, Utah, to conduct the second and final pilot training with the Utah DOT. The agenda (shown in Table 7.1) confined the entire training session to 1 day.

Constraining the meeting to 1 day enabled the team to further gauge the training without providing the full training. This was accomplished by providing only an overview of Methods 2–4.

The research team also allowed time for presentation of a webinar to gain feedback on a shorter training program. The agenda called for three different webinars to be offered simultaneously; however, this approach was modified during the training, and only one webinar was delivered.

Forty-six people attended the session, and 23 participants turned in assessments. Similar to the pilot training in Kansas City, Missouri, in March, the participants were asked to respond to questions about the training modules and the 5DPM concept. In Utah, the participants were also asked to respond to questions about the webinar.

In Utah, the participants were all from the same DOT, whereas different agencies were represented in the Kansas City training. Unlike the Kansas City training, the Utah training had participants representing a wide range of job titles.

Of the 23 responding participants, 12 had less than 5 years of experience, three had 6 to 10 years, three had 11 to 15 years, one had 16 to 20 years, and four had more than 21 years. The job titles represented among the group included the following:

- Business analyst
- Design/environmental engineer
- Design manager
- Design squad leader
- Director, asset management
- Engineer
- GIS analyst
- Pavement engineer
- Preconstruction
- Program manager
- Program manager–safety

Table 7.1. Utah DOT Pilot Training Agenda for April 28, 2011

Time	Module	Topic	Remarks
8:00–10:00	0	Introduction and 5DPM	Introduction to 5DPM, includes exercise
10:00–10:20		Module 0 Feedback	
10:30–12:00	1	Define Critical Project Success Factors	Articulate goals; develop metrics to measure success for each dimension; create implementation plan; include exercise
12:00–12:30		Module 1 Feedback and Box Lunch	
12:30–1:00	2–4	Overview of Methods 2–4	Overview of select contract, assemble owner-driven team, and early cost model and finance plan
1:00–2:30	5	Develop Political Action Plans	Identify specific targeted and general project action plan needs
2:30–3:00		Module 5 Feedback	
3:00–3:30		Webinar	Three different webinars will be offered simultaneously
3:30–4:00		Feedback, Assessment, and Closure	

- Project manager
- Research project manager
- Resident engineer
- Right-of-way deputy director
- Support services engineer
- Transportation planning engineer

The participants were asked first to assess Training Modules 0 through 5. Sixteen of the 22 respondents (73%) provided a positive response about the extent to which the training program provided valuable information (Figure 7.3).

Thirty-nine percent (nine respondents) provided a positive response about the extent to which the module program was easy to follow and understand. Thirteen percent (three respondents) provided a negative response in regard to the extent to which the module was a good balance between theory and exercises. Four percent (one respondent) said the participant exercises were not helpful in applying the theory presented. Finally, 14% (three respondents) were negative about recommending the module training to their peers.

A closer examination of the ability to follow and understand the information enabled the researchers to gain a better understanding of the targeted audience for this training (Figure 7.4).

In comparing participant perceptions of the modules to their years of experience in transportation project management, the team found that those with more years of experience appeared better able to follow and understand the information. This makes sense because the researchers are talking about complex projects, and complex projects are more likely to have more-experienced personnel involved.

The participants were also asked the same questions as in the modules about the webinar that was presented (Figure 7.5). There were very few negative responses about the webinar.

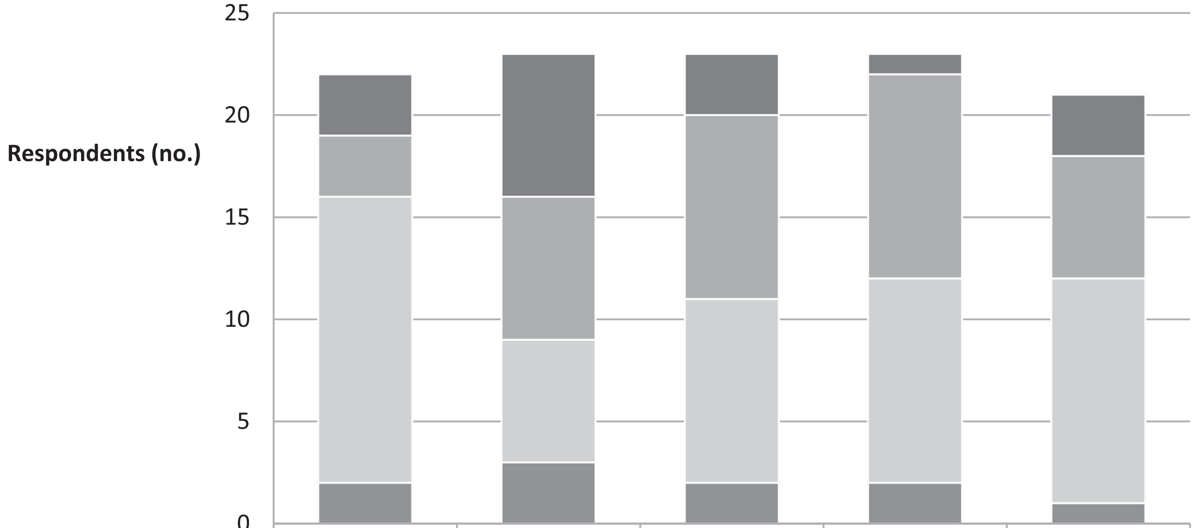
Finally, respondents were asked about their perceptions of the 5DPM concept (Figure 7.6). Again, there were very few negative comments about 5DPM. Four respondents indicated that, based on their experience, the finance dimension does not add to project development theory. This is similar to the findings from the Kansas City training and confirmed by the validation (holdout) studies.

At a discussion after the Utah training, one of the participants pointed out that when the financing dimension comes into play, the project typically becomes complex, and other people, with more of a background in finance, become involved. This discussion gives credence to the findings of the research team that financing is a source of complexity, but it is difficult to model how this complexity has impacts on the project. This difficulty is likely caused by the rapid introduction of several innovative financing approaches that were not clearly understood at the time of this report.

In addition to the written assessment, the participants were asked for verbal feedback throughout the training. From these comments and the assessment, the team made minor revisions to the training materials and started developing more-complete training materials, as some gaps and a need for general revisions were found by the researchers and participants. In summary, the two pilot workshops contributed significantly to the improvement of the draft guide and training program submitted under Task 7.

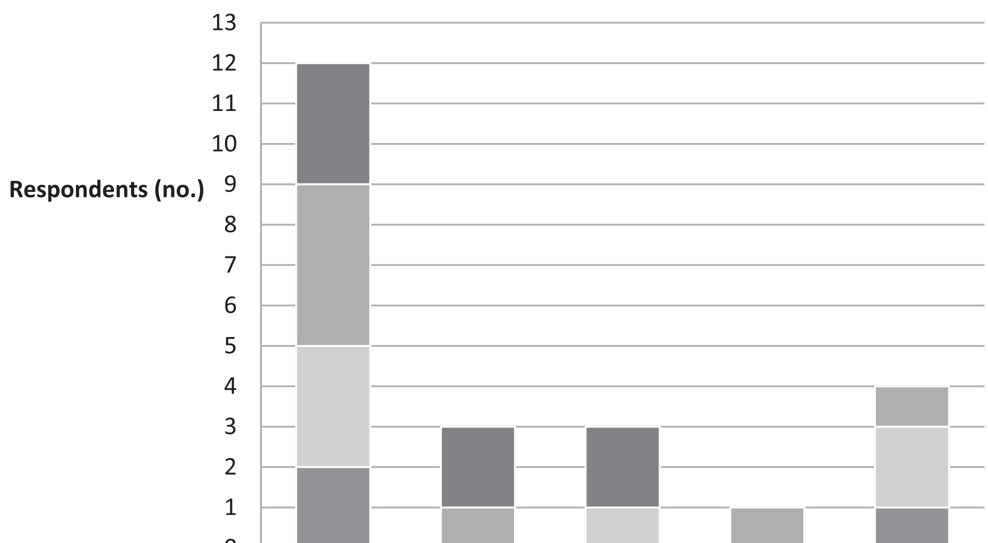
The desired outcomes of the training are for participants to be able to do the following:

- Understand the characteristics of the complex projects.
- Understand the development concept of 5DPM.
- Discuss the differences between traditional projects management and 5DPM.
- Identify required resource allocation to complex projects by using complexity mapping.



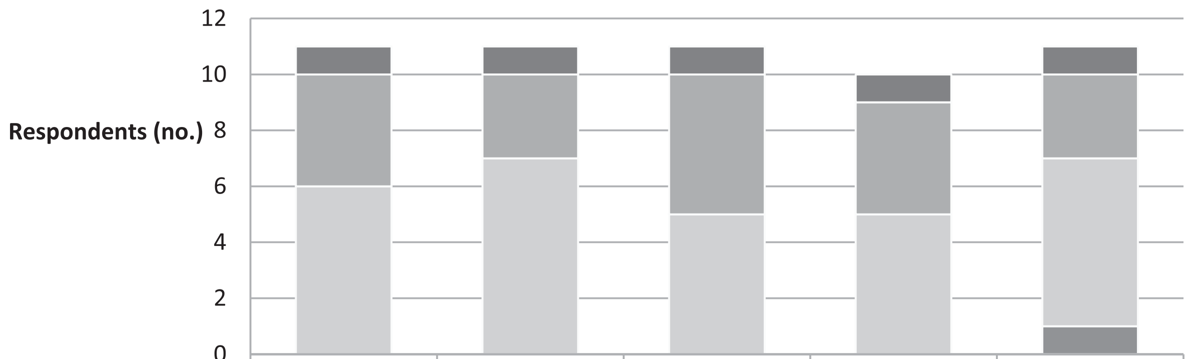
	The module program provided valuable information	The module program was easy to follow and understand	The module program was a good balance between theory and exercises	The exercises were helpful in applying the theory presented	I would recommend the module training to my peers
Totally disagree	0	0	0	0	0
Disagree	3	7	3	1	3
Neither agree nor disagree	3	7	9	10	6
Agree	14	6	9	10	11
Totally agree	2	3	2	2	1

Figure 7.3. Participant perceptions of Training Modules 0–5 for the Salt Lake City, Utah, pilot.



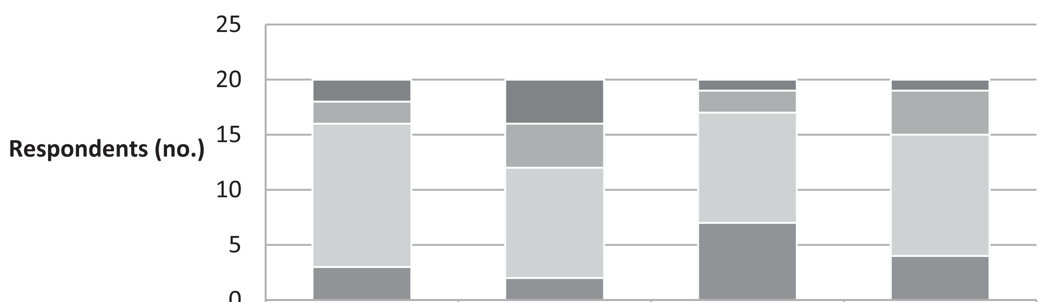
	<5	5-10	11-15	16-20	>21
Totally disagree	0	0	0	0	0
Disagree	3	2	2	0	0
Neither agree nor disagree	4	1	0	1	1
Agree	3	0	1	0	2
Totally agree	2	0	0	0	1

Figure 7.4. Participant understanding of the training, by years of experience, for Modules 0–5, for the Salt Lake City, Utah, pilot.



	The webinar program provided valuable information	The webinar program was easy to follow and understand	The webinar program was a good balance between theory and exercises	The exercises were helpful in applying the theory presented	I would recommend the webinar training to my peers
Totally disagree	0	0	0	0	0
Disagree	1	1	1	1	1
Neither agree nor disagree	4	3	5	4	3
Agree	6	7	5	5	6
Totally agree	0	0	0	0	1

Figure 7.5. Participant perceptions of webinar for the Salt Lake City, Utah, pilot.



	The 5DPM model advances the state of project delivery	Based on my experience, the finance dimension adds to project delivery theory	Based on my experience, the context dimension adds to project delivery theory	The 5DPM model is applicable to future projects in my DOT
Totally disagree	0	0	0	0
Disagree	2	4	1	1
Neither agree nor disagree	2	4	2	4
Agree	13	10	10	11
Totally agree	3	2	7	4

Figure 7.6. Participant perceptions of 5DPM for the Salt Lake City, Utah, pilot.

- Understand the process of mapping project complexity by using 5DPM.
- Name and understand the factors affecting complexity in the five dimensions of project management.
- Discuss the development methods that involve executive-level personnel, as well as project-level personnel.
- Understand that these methods should be implemented at the very earliest stages of the project life cycle to effectively manage complexity.
- Understand that the development methods are also intended to assist project leaders in identifying which tools are needed to effectively manage any specific complex project.
- Name the tools for project management.
- Understand when the execution of the tools is required.
- Understand that outcomes from implementation of individual tools may interact with outcomes or implementation of several other tools and methods.

CHAPTER 8

Workshops

Summary

Task 11 of the research project required conducting six American Association of State Highway Transportation Officials (AASHTO) regional workshops. The purpose of these workshops was to further refine the guide and training materials as well as to transfer the knowledge developed over the course of the project to DOT employees and other interested parties.

The workshops were conducted from August through November 2011 at various locations across the United States (Table 8.1). The locations were selected with support from the FHWA Resource Center in Colorado.

These workshops lasted for one and a half days. The agenda changed slightly over the course of the training, beginning with the agendas shown in Table 8.2 in Ames, Iowa, and ending with the one shown in Table 8.3 for the last two pilot training sessions.

The changes reflect refinements in the training materials. The changes included the presentation order and naming of the methods *assemble project team* and *select contracting arrangements,* and the naming of the method *develop project action plans.* The exercises for the first two methods mentioned were also combined. These changes and others were made on the basis of the training assessment (Appendix E) collected throughout the training sessions.

In all, 139 participants turned in assessments: 31 from the Ohio training, 40 from California, 36 from Texas, 11 from New York, and 21 from Florida. No assessments were collected from the experimental Iowa workshop, which was videotaped.

Participant Demographics

Employer

The majority of the participants (66%) worked for state DOTs; the next largest employer was the FHWA (24%). All other employers represented about 10% of attendees (Figure 8.1).

Age

Forty percent of attendees were between 41 and 50 years of age, and 30% were 51 to 60 years. Eighteen percent were 31 to 40 years of age, 8% were younger than 30 years, and 4% were older than 60 years (Figure 8.2).

Gender

Eighty-one percent of attendees were male, and 19% were female (Figure 8.3).

Educational Background

Sixty-nine percent of attendees had undergraduate degrees, 29% had master's degrees, and 2% had terminal degrees (one PhD and one JD) (Figure 8.4).

Job Title

The disciplines represented were widely distributed: Project management had the largest representation (24%), the design disciplines had the next largest representation (19%), and transportation engineering had the third largest representation (12%). The remaining 45% of attendees came from nine other disciplines. Approximately 9% indicated they were directors, administrators, or supervisors (Figure 8.5).

Table 8.1. Training Workshop Dates and Locations

Date	Location
August 16–17, 2011	Ames, Iowa
September 8–9, 2011	Austin, Texas
September 21–22, 2011	Los Angeles, California
September 28–29, 2011	Columbus, Ohio
October 17–18, 2011	Orlando, Florida
November 3–4, 2011	Albany, New York

Table 8.2. Training Agenda at the Early Training Workshops

Time	Module	Topic	Remarks
Day 1			
8:00–11:00	0	Introduction and 5DPM	Includes group exercise and break
11:00–12:00	1	Define Critical Project Success Factors	Includes group exercise
12:00–12:30		Lunch	Box lunch provided
12:30–1:00	1	Define Critical Project Success Factors	
1:00–2:15	2	Select Contracting and Delivery Methods	Includes group exercise
2:15–2:30		Break	
2:30–4:00	3	Assemble Owner-Driven Project Team	Includes group exercise
Day 2			
8:00–9:30	4	Prepare Early Cost Model and Finance Plan	Includes group exercise
9:30–9:45		Break	
9:45–11:15	5	Define Political Action Plans	Includes group exercise
11:15–11:45		Feedback, Assessment, and Closure	

Table 8.3. Training Agenda for Last Two Training Workshops

Time	Module	Topic	Remarks
Day 1			
8:00–11:30	0	Introduction and 5DPM	Includes group exercise and break
11:30–12:00		Lunch	Box lunch provided
12:00–2:00	1	Define Critical Project Success Factors	Includes group exercise
2:00–2:30	2	Assemble Project Team	
2:30–2:45		Break	
2:45–4:00	3	Select Project Arrangements	Includes group exercise
Day 2			
8:00–9:30	4	Prepare Early Cost Model and Finance Plan	Includes group exercise
9:30–9:45		Break	
9:45–11:15	5	Develop Project Action Plans	Includes group exercise
11:15–11:45		Feedback, Assessment, and Closure	

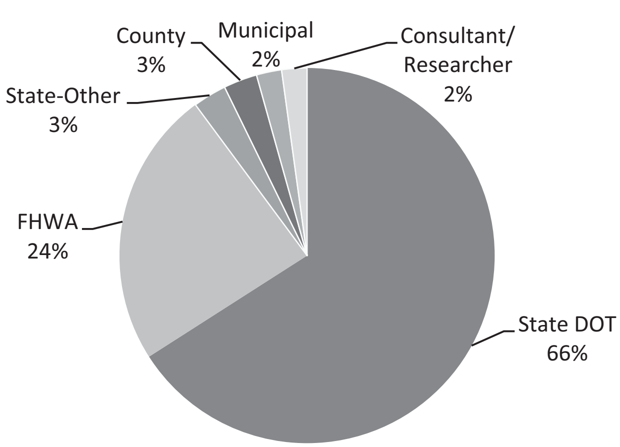


Figure 8.1. Participant employers.

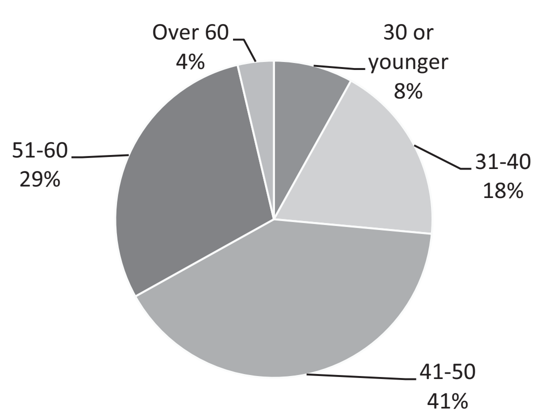


Figure 8.2. Participant age.

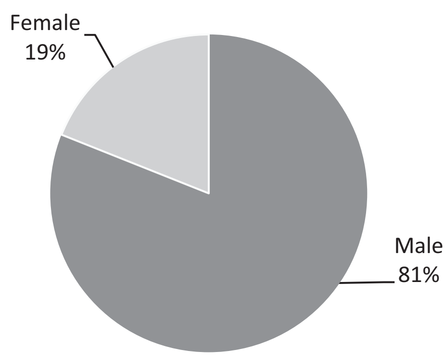


Figure 8.3. Participant gender.

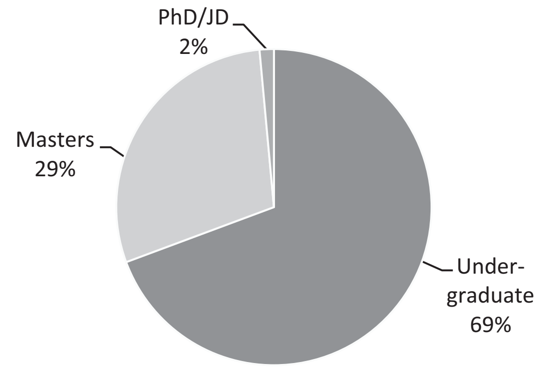


Figure 8.4. Participant education level.

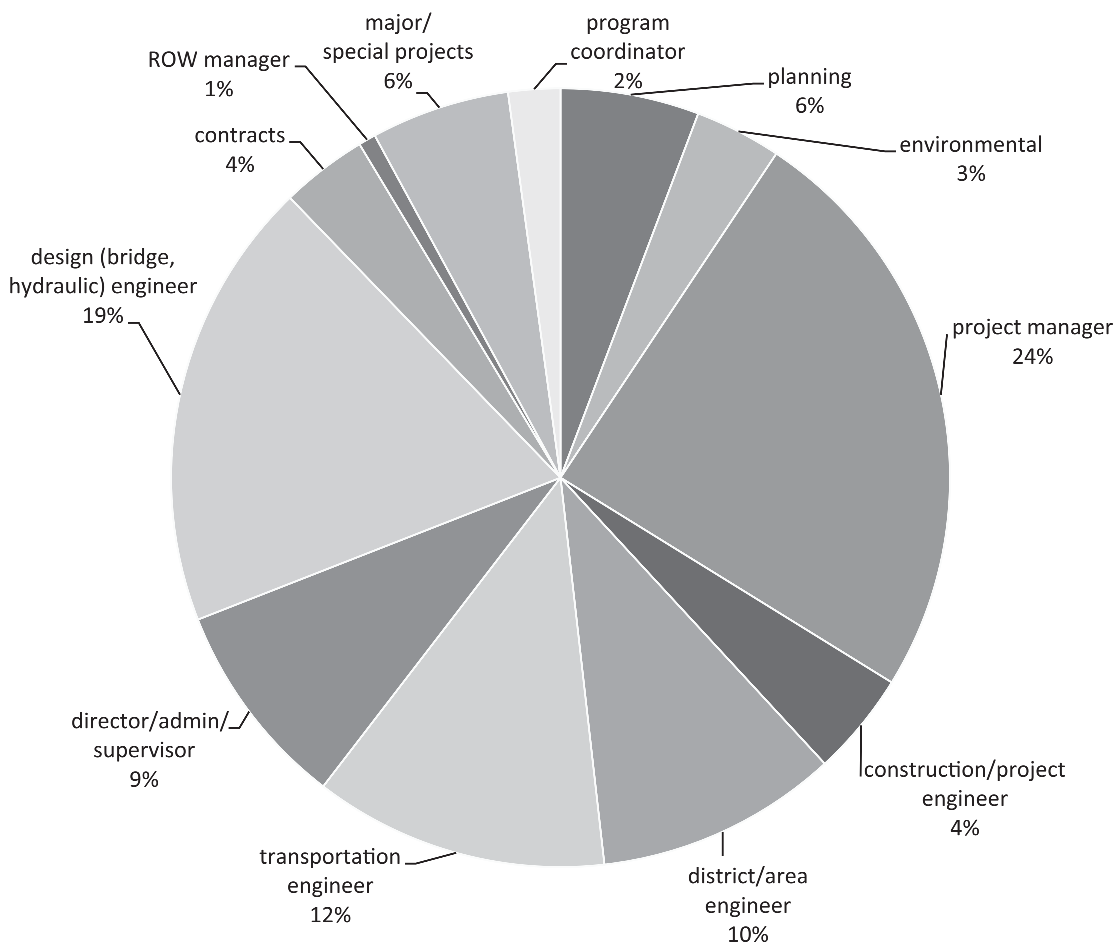


Figure 8.5. Participant job description.

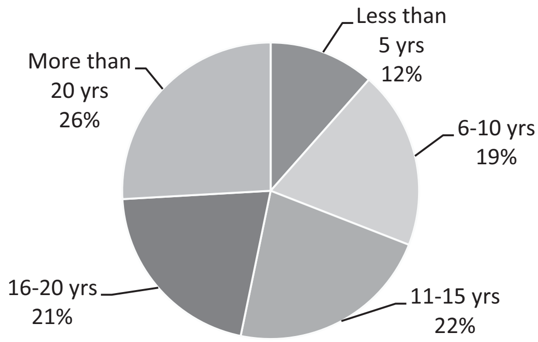


Figure 8.6. Participant years of experience.

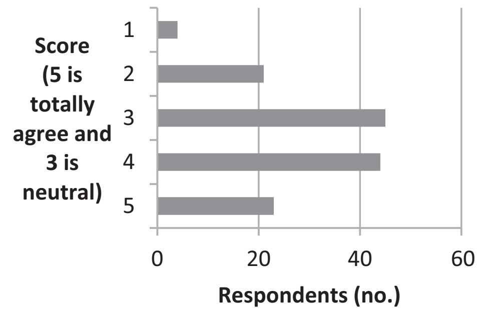


Figure 8.8. The module program was easy to follow and understand.

Years Worked in Transportation Project Management

The number of years worked in transportation was well distributed among attendees, ranging from 12% for those with less than five years of experience to 26% for those with more than 20 years of experience (Figure 8.6).

Perceptions About the Modules Training Program (Modules 0 through 5) and Refinements

A scale from 1 to 5 was used in the assessment (5 = totally agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree, and 1 = totally disagree).

Seventy-seven percent of participants responded that they totally agree or agree that the module program provided valuable information (Figure 8.7).

The major area of concern about the training module program was responses to the statement, "the module program was easy to follow and understand," with less than 50% replying that they totally agree or agree with this statement (Figure 8.8).

One of the modules was retitled, the order of presentation of some material was changed, additional case study examples were added, and—most important—four of the five in-class exercises were significantly revised to make them more explicit and more directly related to the module slides and guide.

Sixty-six percent responded that they totally agree or agree that the module program has a good balance between theory and exercises (Figure 8.9).

Sixty percent responded that they totally agree or agree that the exercises were helpful in applying the theory presented (Figure 8.10).

Sixty-two percent responded that they totally agree or agree that they would recommend the module program to their peers (Figure 8.11).

Ninety-four percent responded that the delivery methods were appropriate (Figure 8.12).

Eighty-two percent responded that the level of material presented was appropriate (Figure 8.13).

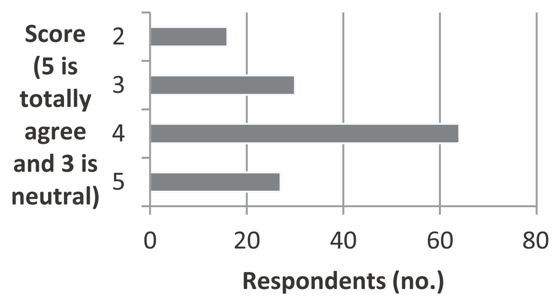


Figure 8.9. The module program has a good balance between theory and exercises.

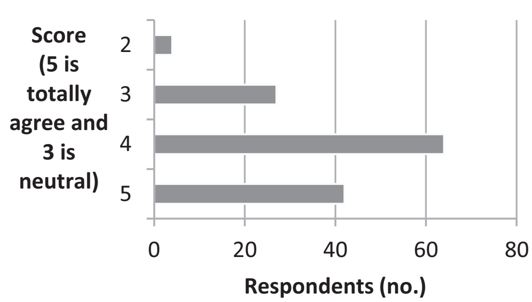


Figure 8.7. The module program provided valuable information.

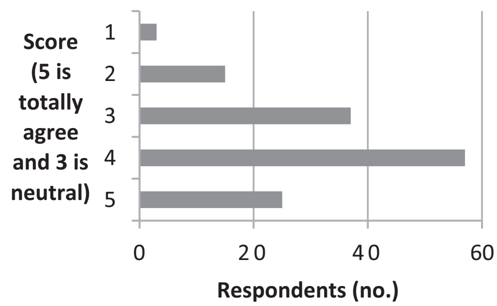


Figure 8.10. The exercises were helpful in applying the theory presented.

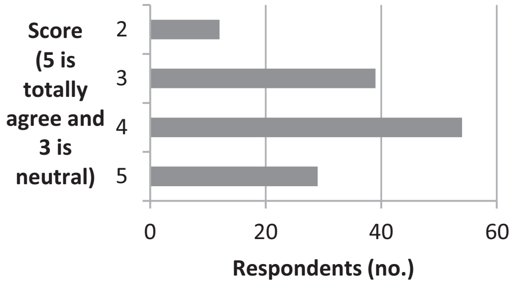


Figure 8.11. I would recommend the module program to my peers.

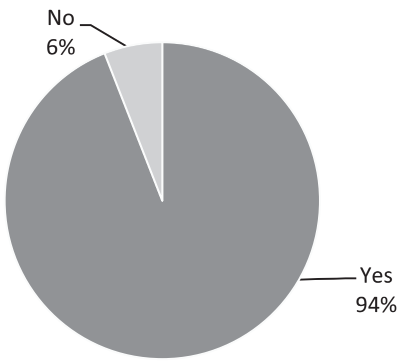


Figure 8.12. Was the delivery method appropriate?

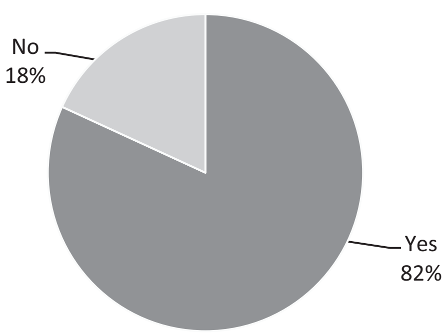


Figure 8.13. Was the level of information presented appropriate?

The guide was revised based on the assessment comments from the training sessions, and the guide and training module presentations will be linked more directly in the final version of materials.

Perceptions About the 5DPM Model and Refinements

A scale of 1 to 5 was used (5 = totally agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree, and 1 = totally disagree).

Seventy-five percent responded that they totally agree or agree with the statement that the 5DPM model advances the state of project delivery (Figure 8.14).

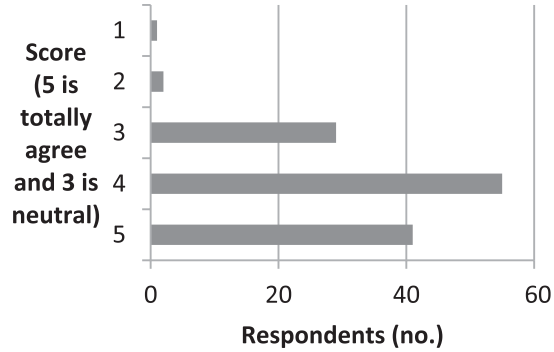


Figure 8.14. The 5DPM model advances the state of project delivery.

Seventy-six percent responded that they totally agree or agree with the statement that based on their experience, the finance dimension adds to project delivery theory (Figure 8.15).

Eighty-five percent responded that they totally agree or agree with the statement that based on their experience, the context dimension adds to project delivery theory (Figure 8.16).

Eighty-nine percent responded that they totally agree or agree with the statement that the 5DPM model is applicable to future projects in their DOTs (Figure 8.17).

On the basis of these highly favorable assessments, the research team decided that the concepts included in the guide, training modules, and webinars were appropriate, and significant changes in content were not warranted.

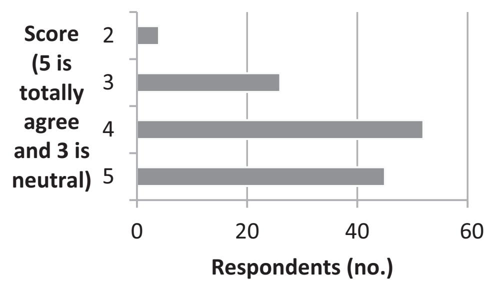


Figure 8.15. Based on my experience, the finance dimension adds to project delivery theory.

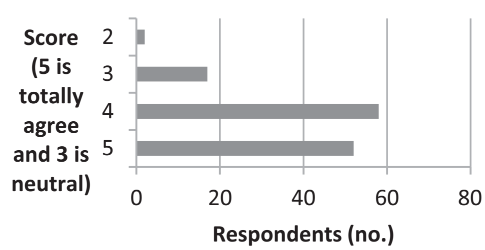


Figure 8.16. Based on my experience, the context dimension adds to project delivery theory.

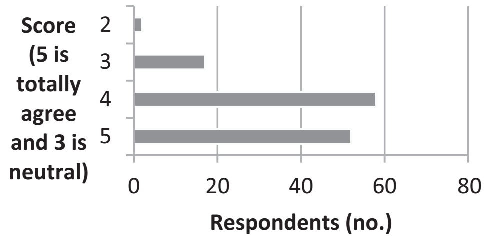


Figure 8.17. The 5DPM model is applicable to future projects in my DOT.

Open-Ended Comments and Refinements

A significant amount of feedback on the assessment was collected through open-ended comments. The majority of the comments related to the confusing nature of the module titles, module numbering, poor integration of the guide, exercises, module presentation slides, and case study examples. Many of these comments have been addressed in clarifying changes to the module presentation slides and significant modification of in-class exercises.

Revision of the guide was first completed in 2012, addressing the training integration and case study comments as well.

In addition, several comments were made as to the appropriate audience for the training sessions. Responses were widely split among centralized DOT training, divisional DOT training, FHWA-sponsored training, and project-based training. Consequently, final drafts of all material were prepared for use in a project-based training, all of whose attendees shared in-depth knowledge of a common project.

The guide and most of the training module presentation slides could be used with minor adaptations in a class-based delivery to attendees who do not share in-depth knowledge of a common project, but the in-class exercises would need to be revised significantly.

CHAPTER 9

Conclusions and Recommendations

The objectives of the SHRP 2 Renewal Project R10 were as follows:

- Develop tools that help DOTs get in, get out, and stay out.
- Identify project management practices to deliver complex projects using innovative strategies.
- Develop and deploy tools.
- Facilitate a fundamental change in rehabilitating transportation infrastructure.

The researchers achieved these objectives through a multistep approach, beginning with a literature review. This literature review revealed that complex projects may not be managed successfully through the traditional "iron triangle" of project management: cost, budget, and technical dimensions.

Complex projects need a different approach that includes the five dimensions of cost, budget, technical, context, and financing. The researchers identified factors to define each of the five dimensions.

The next step of the research was a series of case studies. The researchers used the case studies to verify the dimensions, identify the factors within each of these dimensions that have an impact on a specific project, and define and develop the methods and tools that are being used to manage these factors and, therefore, the dimensions of complexity.

In addition to identifying the factors and tools, the researchers mapped the complexity of each case study project. Eighteen case studies were assessed in this step; 15 were in the United States and three were international. From these cases, the researchers identified and further developed a number of methods and tools.

More specifically, the researchers examined the case studies to determine similarities. They identified five methods in all of the case study projects that are overarching and that reason indicated are needed on all projects.

The researchers also identified 13 tools. These tools were found in multiple projects, but not all, and were determined to be more project specific. The researchers found that not all of the tools are needed on all projects. The researchers verified the mapping, methods, and tools on two additional case study projects.

From the information collected, the researchers developed the guide and training materials, while keeping the DOT practitioner in mind. The guide facilitates the use of effective strategies in managing complex projects. To help improve the state of the practice, the guide focuses on practical tools and techniques designed to be immediately beneficial to transportation professionals.

The training supports the implementation of the approach presented in the guide. The training follows the flow and format of the guide produced as part of this project and further refined many times since its initial draft. The training serves as an introduction to 5DPM and the methods and tools found in successfully delivered complex projects.

The training was tested first in a shortened form at two different locations. Modifications were made—and the training was delivered—at six AASHTO regional workshops. The focus of this on-site training was to introduce the 5DPM concept and the five methods. Participants from a number of state transportation agencies participated, along with personnel from the FHWA and private industry.

The workshop consisted of lectures and exercises for the participants. This format enables participants to apply what has been discussed right away. Participants are encouraged to use the exercises to explore one of their current projects in the group setting.

From the six workshops, participants submitted 139 assessments. The team used these assessments to further modify the training. Specifically, the guide and training were aligned on the basis of these modifications after the final workshop. The guide and training materials maintain their practice-oriented focus for implementation of the 5DPM concept.

In addition to the on-site training, a set of 13 webinars was developed. The webinars allow a participant to return from the on-site training and either watch the applicable tool webinars individually or to ask a project team member to watch a webinar on a specific tool.

Each webinar begins with an introduction to the 5DPM concept as a refresher to the participant or an introduction to the concept for participants who did not attend the training, and it allows participants to skip ahead with a click of their mouse. (The participant can skip the introduction portion of the webinar if he or she does not need to watch that segment.) Each webinar then provides more specifics about the tool and asks the participant to complete a practice exercise. The team has not done an assessment of the webinars at this time. The training materials are available online at www.trb.org/Publications/Blurbs/167482.aspx.

Further Research Efforts

Many additional efforts stem from this project, including additional training, modification of the case study report, expansion of the webinar concepts, development of the guide and training materials for noncomplex projects, and integration of the concepts with current DOT practices.

The R10 project included six training sessions. The positive responses from these six training sessions demonstrate the desire to have additional training in this area.

One possibility for additional efforts is to offer more training sessions. These sessions would use the final version of the guide and training materials. The sessions could be offered in regional or specific transportation agency settings. The sessions would, again, last for a day and a half, and participants would be encouraged to use a current project of their choosing for the exercises completed in the workshop.

During the early phases of the project, the research team developed a case study report (available at www.trb.org/Main/Blurbs/167481.aspx), and a summary of each case study project is provided in the guide.

A number of training participants voiced an interest in additional information about the case studies, and the team has given it by providing the summaries. However, over the course of the research, the team found that a full case study report may be beneficial in a longer form. The initial case study report was developed before the final version of the guide and training materials. Additional time could be spent aligning the case study report with the final versions of the guide and training materials for publication.

The primary focus of the team in development of the guide and the training materials was the 5DPM concept and the methods to use on every project. The research team did not spend as much time fleshing out the information on the tools, and the webinars initially produced for the tools were not evaluated for effectiveness by users.

Additional time could be spent developing each of the tools in greater detail, and the webinar concept could be evaluated and modified as needed. Further development of each tool would include identifying the states (those included in the case studies), as well as other possible users or projects, that have used it and then exploring its use.

Evaluation of the webinar concept would incorporate an assessment by the webinar participants and compilation of these evaluations. Modifications could be made on the basis of the comments received.

The research team did observe during the development of the webinars that a script needs to be prepared for delivery of the webinar before recording. In addition, a member of the research team delivered the voice portion of the webinars and recommended hiring someone who does professional voice recordings to deliver the content.

Throughout the delivery of the training, participants noted that concepts could be applied to noncomplex projects, but only at a different level of intensity. This observation could be further explored to determine what level of effort may be required for the more routine projects. This could include development of a new guide and training materials that have a different focus and different level of effort for the participants.

Integration of the 5DPM concept into all projects in a transportation agency would then require working directly with a transportation agency to evaluate its current practices and how they would need to be modified to incorporate the 5DPM model.

Finally, although a number of participants in the training applied the guide and training to projects by participating in exercises, it would be beneficial to work closely with a project team to observe its integration of the concepts into an actual project and the impact on it.

A longitudinal study would be necessary, and the researchers would need to become entrenched in the project team to observe and work through issues that develop with the 5DPM process. Projects selected for implementation would need to be selected early in the project development process.

To aid the researchers, the project would also need to be developing and moving forward. The project team would need to have the authority to make decisions and work with the 5DPM process, which would most likely necessitate working outside of the norm of the transportation agency.

The project team would need to go through the training, which would be expanded to allow for more time in its exercise portion to more fully apply the concepts and flesh out details.

The project team would need to be revisited through phone and on-site visits for a period after the initial visit. The purpose of this additional follow-up would be to follow the concepts and determine the direction of development and possible realignment of the project team with the 5DPM concept or the guide and training materials.

The differential impact of the 5DPM process would still be difficult to evaluate. It is impossible to have two identical projects developed side by side, so the evaluation would need to be done in a manner that assesses the impacts and may be based on what the project team has experienced in previous projects.

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APPENDIX A

Literature Tables

The following tables list the publications that the R10 team reviewed, in terms of the cost (Table A.1), schedule (Table A.2), technical (Table A.3), context (Table A.4), and financing (Table A.5) dimensions.

Table A.1. Cost Dimension

	Risk		Preliminary Program		Planning and Construction			Issues	
Literature	**Contingency**	**Uncertainty**	**Estimates**	**Cost Allocation**	**Control**	**Optimization**	**Incentive**	**Material**	**Road User**
Gransberg and Kelly (2008)	◆	◆	◆					◆	
Anderson et al. (2009)			◆		◆				
FTA (2003)		◆	◆		◆		◆		
Molenaar and Wilson (2009)	◆	◆	◆						
FHWA (2009a)					◆				
Lockhart et al. (2008)		◆	◆						
Fischer (2000)					◆				
Batson (2009)					◆				
Edwards et al. (2009)		◆							
Kasi (2007)	◆		◆	◆	◆				
Cristobal (2009)						◆			
Porro and Schaad (2002)	◆	◆							
Kyte et al. (2004)			◆						
Brown and Marston (1999)				◆	◆		◆		
GAO (1997)			◆		◆				
Sangrey et al. (2003)		◆	◆						
Gray and Larson (2008)		◆			◆				

(continued on next page)

Table A.1. Cost Dimension (continued)

Literature	Risk		Preliminary Program		Planning and Construction			Issues	
	Contingency	Uncertainty	Estimates	Cost Allocation	Control	Optimization	Incentive	Material	Road User
Kerzner (2006)		◆							
Sorel (2004b)					◆	◆			◆
Allen (2004)	◆	◆					◆		
Sinnette (2004)	◆	◆	◆		◆				
Gransberg et al. (2007)			◆						
Hertogh et al. (2008)			◆				◆		
Touran (2006)	◆	◆							
Ashur and Crockett (1997)			◆						
Gransberg and Riemer (2009)	◆		◆						
Booz Allen Hamilton (2005)					◆				
Schneck et al. (2009)	◆	◆	◆						
Martin and Does (2005)						◆			◆
FHWA (2007b)	◆	◆	◆					◆	
Casavant et al. (2007)	◆	◆	◆		◆			◆	

Table A.2. Schedule Dimension

Literature	Time	Risk	Planning and Construction				Technology		Mathematical Modeling
			Milestones	Control	Optimization	Resource Availability	Visualization	System/ Software	
Sanvido et al. (1992)	◆			◆	◆				
Zhang (2005)		◆				◆			◆
Ashley et al. (1987)				◆	◆				
Pennsylvania DOT (2009)				◆					
Lam et al. (2008)	◆			◆					
Levitt (1984)				◆	◆				
Tatum (1984)					◆				
McKim et al. (2000)		◆		◆					
Khodakarami et al. (2007)		◆							◆
FHWA (2009b)	◆	◆							

(continued on next page)

Table A.2. Schedule Dimension (continued)

Literature	Time	Risk	Planning and Construction				Technology		Mathematical Modeling
			Milestones	Control	Optimization	Resource Availability	Visualization	System/ Software	
Kog et al. (1999)				◆					
Butts and Linton (2009)	◆	◆							
Booz Allen Hamilton (2005)	◆			◆	◆				
Clift and Vandenbosch (1999)				◆					
Commonwealth of Australia (2006)				◆					
Thomas et al. (1985)	◆								
Pickrell (1990)	◆								
Maylor (2001)			◆	◆	◆				
Bernstein (1983)	◆			◆	◆				
FTA (2003)		◆	◆	◆	◆				
Mudholkar (2008)				◆					
FHWA (2009a)				◆	◆				
Lockhart et al. (2008)		◆							
Fischer (2000)							◆		
Batson (2009)				◆					
Edwards et al. (2009)		◆							
Cristobal (2009)					◆	◆			
Porro and Schaad (2002)		◆							
Schmitt et al. (1997)				◆				◆	◆
Brown and Marston (1999)		◆		◆	◆				
Lee et al. (2002)					◆				
Sangrey et al. (2003)		◆			◆				
Gray and Larson (2008)				◆		◆			
Schexnayder and Mayo (2003)		◆		◆					
Kerzner (2006)		◆		◆					
Sorel (2004b)		◆		◆	◆	◆			
Allen (2004)		◆							
Winter and Smith (2006)				◆					
Touran (2006)		◆							
Hertogh et al. (2008)				◆					

(continued on next page)

Table A.2. Schedule Dimension (continued)

Literature	Time	Risk	Planning and Construction				Technology		Mathematical Modeling
			Milestones	Control	Optimization	Resource Availability	Visualization	System/ Software	
Dolson (1999)								◆	
Whited and Gatti (2007)		◆			◆				
Abdul-Malak and Hassanein (2002)			◆		◆				
Crossett and Hines (2007)	◆								
Gamez and Touran (2009)	◆								
Molenaar (2005)		◆							
Flyvbjerg et al. (2004)			◆	◆					
Merrow et al. (1988)						◆			
Touran et al. (1994)	◆	◆	◆	◆					
Mahalingam et al. (2010)				◆			◆		
Feng et al. (2010)					◆		◆		◆
Russell et al. (2009)							◆	◆	
Jongeling and Olofsson (2007)						◆	◆	◆	
GSA (2009)							◆		

Table A.3. Technical Dimension

Literature	Scope	Internal Structure	Contract				Design			Construction				Technology		
			Prequalification	Warranties	Disputes	Delivery Method	Method	Reviews/ Analysis	Existing Conditions	Quality	Safety/ Health	Optimization	Climate	Usage	Intelligent Transportation Systems	Automation
Bernstein (1983)							◆	◆		◆						
Dallaire (1977)							◆				◆					
Gransberg and Riemer (2009)			◆							◆	◆					
Konchar and Sanvido (1998)						◆										
FTA (2003)	◆	◆	◆		◆	◆	◆	◆		◆						
Molenaar et al. (2000a)						◆										
FHWA (2009a)	◆				◆		◆	◆						◆		
Schaufelberger (2000)						◆										
Abdul-Malak and El-Saadi (2000)					◆											
Gambatese (2000)											◆					
Fischer (2000)														◆		
Molenaar et al. (2000b)	◆					◆										
Cho et al. (2009)										◆				◆		
El-Asmar et al. (2009)						◆										
Kasi (2007)							◆	◆		◆						
Cristobal (2009)										◆		◆				
McClure et al. (2008)				◆		◆										
Miller and Lantz (2008)	◆															
Bohn and Teizer (2009)					◆									◆		
Kyte et al. (2004)	◆															
Olszak et al. (2007)														◆		
Brown and Marston (1999)		◆					◆							◆		
Pate (2000)		◆	◆		◆		◆	◆								
Capka (2004)	◆	◆														
Broadhurst (2004)		◆						◆								
Gray and Larson (2008)		◆														
Gransberg et al. (2006)	◆	◆				◆	◆									
Schexnayder and Mayo (2003)					◆	◆				◆						

(continued on next page)

Table A.3. Technical Dimension (continued)

			Contract				Design			Construction				Technology		
Literature	Scope	Internal Structure	Prequalification	Warranties	Disputes	Delivery Method	Method	Reviews/ Analysis	Existing Conditions	Quality	Safety/ Health	Optimization	Climate	Usage	Intelligent Transportation Systems	Automation
Beard et al. (2001)			◆			◆	◆									
Sorel (2004b)		◆														
Yakowenko (2004)	◆					◆										
Gransberg and Windel (2008)			◆				◆									
Lopez del Puerto et al. (2008)						◆										
Gransberg and Molenaar (2004)			◆							◆						
Touran et al. (2009)							◆									
Trauner Consulting Services (2007)						◆										
Gransberg et al. (2008)			◆			◆	◆	◆								
Hertogh et al. (2008)																
Mrawira et al. (2002)										◆				◆		
Dolson (1999)						◆	◆	◆						◆		
Gransberg and Riemer (2009)						◆	◆									
Cheng et al. (2000)						◆										
Discetti and Lamberti (2009)								◆								
Sanvido et al. (1992)							◆									
Ashley et al. (1987)	◆	◆					◆	◆								
Levitt (1984)		◆												◆		
Tatum (1984)		◆														
Booz Allen Hamilton (2005)						◆										
Booz Allen Hamilton and Baker, Jr., Inc. (2003)														◆		
Sangrey et al. (2003)								◆								
Schneck et al. (2009)	◆															
Trapani and Beal (1983)		◆					◆	◆	◆							
Martin and Does (2005)									◆		◆		◆			
Crichton and Llwellyn-Thomas (2003)									◆		◆					
Chiu and Teft (2006)							◆	◆	◆							
Casavant et al. (2007)	◆				◆					◆						

Table A.4. Context Dimension

	Stakeholders				Project-Specific			Local Issues												Environmental		Legal/ Legislative		Global/ National		Unusual Conditions	
Literature	Public	Politi-cians	Owner	Juris-dictions	Main-taining Capa-city	Work Zone Visuali-zation	Inter-modal	Social Equity	Demo-graphics	Public Services	Land Use	Growth Induce-ment	Land Acqui-sition	Eco-nomics	Market-ing	Cul-tural	Work-force	Utili-ties	Resource Avail-ability	Sustain-ability	Limi-tations	Proce-dural Law	Local Accep-tance	Eco-nomics	Inci-dents	Weather	Force Majeure
Bernstein (1983)	◆			◆	◆								◆								◆	◆					
FTA (2003)	◆			◆									◆								◆	◆					
Molenaar et al. (2000a)	◆	◆	◆	◆																							
FHWA (2009a)	◆														◆												
El-Assaly and Ellis (2000)																				◆							
Edwards et al. (2009)	◆	◆	◆	◆																							
GAO (2008)			◆	◆															◆		◆						
Miller and Lantz (2008)			◆	◆																							
Olszak et al. (2007)	◆		◆																								
Brown and Marston (1999)	◆												◆					◆			◆						
Lee et al. (2002)					◆														◆								
Lee et al. (2000)					◆														◆								
Pate (2000)	◆		◆	◆																							
Capka (2004)	◆	◆																			◆						
Broadhurst (2004)	◆		◆	◆			◆						◆								◆						
Gray and Larson (2008)			◆													◆								◆			
Sorel (2004a)	◆	◆	◆	◆		◆									◆						◆						
Gransberg and Molenaar (2008)			◆																				◆				
Hertogh et al. (2008)	◆	◆	◆	◆				◆					◆	◆		◆			◆		◆	◆					

(continued on next page)

Table A.4. Context Dimension (continued)

	Stakeholders				Project-Specific			Local Issues												Environmental		Legal/ Legislative		Global/ National		Unusual Conditions	
Literature	Public	Politicians	Owner	Jurisdictions	Maintaining Capacity	Work Zone Visualization	Intermodal	Social Equity	Demographics	Public Services	Land Use	Growth Inducement	Land Acquisition	Economics	Marketing	Cultural	Workforce	Utilities	Resource Availability	Sustainability	Limitations	Procedural Law	Local Acceptance	Economics	Incidents	Weather	Force Majeure
Discetti and Lamberti (2009)	◆	◆	◆	◆																							
Miller et al. (2000)																◆											
Davies and Binsted (2007)	◆							◆													◆						
McLeod (1996)																					◆						
Chou et al. (2009)																		◆									
Kraus et al. (2008)																		◆									
Ashley et al. (1987)														◆							◆						
Booz Allen Hamilton (2005)	◆	◆	◆	◆																							
Booz Allen Hamilton and M. Baker, Jr., Inc. (2003)																					◆						
Trapani and Beal (1983)	◆			◆																	◆						
TransTech et al. (2004)	◆	◆	◆	◆																							
TAC (2009)	◆	◆	◆	◆				◆						◆						◆							
Martin and Does (2005)	◆		◆		◆	◆															◆					◆	
Crichton and Llewellyn-Thomas (2003)	◆	◆	◆		◆		◆											◆	◆		◆						
Barnes and Langworthy (2004)	◆	◆	◆				◆	◆																			
Chiu and Teft (2006)	◆	◆		◆	◆								◆			◆											
Casavant et al. (2007)																			◆						◆		◆

Table A.5. Financing Dimension

	Process				Public					Revenue Stream			Asset Value			Project Delivery Method	Risk	
Literature	**Legislative**	**Uniformity**	**Transition**	**Project Manage-ment Training**	**Federal**	**State**	**Bond**	**Borrowing Against Future**	**Advanced Construction**	**Revenue Generation**	**Vehicle Miles Fees**	**Cordon/ Congestion Pricing**	**Monetization of Existing Assets**	**Fran-chising**	**Carbon Credit Sales**	**PPP/CDA/ Concessions**	**Commodity-Based Hedging**	**Global Participation**
Marshall and Rousey (2009)				◆	◆	◆	◆											
Heiligenstein (2009)	◆			◆		◆	◆	◆								◆		
Drike et al. (2002)	◆	◆			◆	◆	◆											
FHWA (2007a)					◆	◆	◆		◆									
Balducci (2002)	◆		◆		◆	◆	◆	◆	◆	◆	◆	◆						
Dierkers and Mattingly (2009)	◆			◆	◆	◆	◆			◆	◆	◆			◆			
Kirby (2007)	◆		◆					◆				◆	◆					◆
Orski (1999)			◆	◆								◆	◆	◆				
MACED (2008)				◆											◆			
Courteau et al. (2007)				◆													◆	◆
Price (2002)			◆	◆	◆	◆	◆	◆	◆	◆	◆		◆					◆
Klijn et al. (2008)		◆	◆	◆												◆		
Little (2006)	◆	◆	◆		◆	◆	◆				◆	◆						

(continued on next page)

Table A.5. Financing Dimension (continued)

	Process				Public					Revenue Stream			Asset Value			Project Delivery Method	Risk	
Literature	**Legislative**	**Uniformity**	**Transition**	**Project Manage-ment Training**	**Federal**	**State**	**Bond**	**Borrowing Against Future**	**Advanced Construction**	**Revenue Generation**	**Vehicle Miles Fees**	**Cordon/ Congestion Pricing**	**Monetization of Existing Assets**	**Fran-chising**	**Carbon Credit Sales**	**PPP/CDA/ Concessions**	**Commodity-Based Hedging**	**Global Participation**
Johnston and Gudergan (2007)	◆		◆													◆		◆
Ortiz and Bux-baum (2008)			◆													◆		
Chege and Rwelamila (2001)								◆		◆			◆			◆		◆
Gokan (2002)			◆		◆	◆	◆											◆
Persad et al. (2008)	◆		◆		◆	◆	◆	◆								◆		
Harder (2009)	◆		◆	◆			◆	◆		◆						◆		
Vining and Boardman (2008)			◆		◆	◆							◆			◆		
Gallay (2006)	◆	◆			◆	◆				◆						◆		
Brown et al. (2009)			◆			◆				◆						◆		◆
GAO (2009)	◆				◆	◆										◆		◆
Resource Sys-tems Group (2007)		◆	◆		◆	◆	◆	◆	◆		◆					◆		
Bettignies and Ross (2004)	◆				◆	◆				◆						◆		◆
Morallos and Amekudzi (2008)	◆	◆			◆	◆										◆		
Mathur and van Aalst (2009)			◆		◆	◆	◆	◆		◆						◆		◆
Henkin (2009)	◆	◆		◆	◆	◆	◆	◆		◆	◆							

APPENDIX B

List of Potential Case Studies

The following locations are possible sites for case studies.

1. Doyle Drive, Route 101, City and County of San Francisco, including Richardson Avenue from Lombard Street to Golden Gate Bridge, California
2. I-80/San Francisco-Oakland Bay Bridge (East Span), San Francisco-Oakland, California
3. I-95/New Haven Harbor Crossing, New Haven, Connecticut
4. I-595 Corridor Improvements Ft. Lauderdale, Florida
5. Miami Intermodal Center, Miami, Florida
6. Port of Miami Tunnel and Access Improvement Project, Miami, Florida
7. Louisville Southern Indiana Ohio River Bridges Project, Kentucky/Indiana (Louisville), Kentucky
8. InterCounty Connector, Montgomery and Prince George's Counties, Maryland
9. Detroit River International Crossing, Detroit, Michigan
10. New Mississippi River Bridge, Illinois/Missouri (St. Louis), Missouri
11. I-93 Reconstruction, Salem to Manchester, New Hampshire
12. I-40 Crosstown, Oklahoma City, Oklahoma
13. North Tarrant Express, Fort Worth, Texas
14. Capital Beltway HOT Lanes, Northern Virginia
15. I-95/Woodrow Wilson Bridge, Virginia, Maryland, and Washington, D.C.
16. Pocahontas Parkway refinancing, Richmond metro area, Henrico County, Virginia
17. I-25/I-225 Southeast Corridor (T-REX), Denver, Colorado
18. I-15 Corridor, Salt Lake County, Salt Lake City, Utah
19. I-95/I-395/I-495 Springfield Interchange, Springfield, Virginia

APPENDIX C

Case Study Questionnaire

Case X—NAME

Project Information

Project Name:
Name of Agency:
Location:
Project Delivery Method (*DBB, DB, CMR, PPP, etc.*):
Procurement Procedure (*QBS, Best-Value, Low Bid*):
Contract Payment Provisions (*Lump Sum, GMP, Cost* +):

Project Description

Brief 2–3 sentence description of the scope of work (e.g., *The project consisted of upgrading 3 miles of 4-lane urban freeway to include new HOV lanes in both directions as well as reconfiguring existing interchanges on the route to accommodate ramp metering*).

The case study project includes:

- *3 miles of new HOV lanes each direction.*
- *Dowel bar retrofit and repairing existing concrete pavement following by diamond grinding.*
- *Relocation of approximately 50 miles of utilities.*
- *Widening of 14 on-ramps to accommodate queuing for ramp-metering system.*
- *A state-of-the-art communications system to furnish real-time accident and congestion reporting.*
- *Etc.*

Project Complexity Profile

Why is this a complex project?
Owner's reasons for treating it as complex:
5D Map after Garvin's approach

Project Financial and Schedule Information

Original Total Awarded Value of Project: $
Final Total Awarded Value of Project: $
Project Schedule:
Project Approved to Start Process: *Date*
Initial Advertising: *Date*
RFP Issued to Shortlist: *Date*

Contract Award: *Date*
Original Project Delivery Period: *Years and months plus completion date*
Final Project Delivery Period: *Years and months plus completion date*

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

PDM	No. Projects	No. Complex Projects	Typical Complex Project Type for PDM	Remarks
DBB	*1–5; 6–10; 10–20; >20*	*1–5; 6–10; 10–20; >20*		
CMR	*1–5; 6–10; 10–20; >20*	*1–5; 6–10; 10–20; >20*		
DB	*1–5; 6–10; 10–20; >20*	*1–5; 6–10; 10–20; >20*		
Etc.	*1–5; 6–10; 10–20; >20*	*1–5; 6–10; 10–20; >20*		

Agency Project Delivery Decision-Making Process: Describe process for selecting a PDM for the case study project.
Reasons for Selecting Project Delivery Method (most significant reason): Cite the major reasons for selecting PDM on this project.

Case Study Project Management Factors

From the lists below, check which factors in each dimension are considered more important in a complex project than in a routine project. Differentiate between those that result in a benefit to the project or agency and those that impose a constraint on the project or agency.

Factors	Cost	Schedule	Technical	Financing	Context
Considered a *benefit* of the chosen delivery system to this project Remarks on above benefits Considered a *constraint* of the chosen delivery system to this project Remarks on above constraints Summary remarks	Project estimates Uncertainty Contingency Project costs—i.e., road user costs, right-of-way Design to a budget Project estimates Uncertainty Contingency Project costs—i.e., road user costs, right-of-way Design to a budget	Time Schedule risk Prescribed milestones Availability of resources Time Schedule risk Prescribed milestones Availability of resources	Design Scope of design and construction work Quality Need for integrated delivery Design Scope of design and construction work Quality Need for integrated delivery	Public funds Public–private partnerships Comprehensive development agreements Concession Bond-funding Borrowing against future public funding (GARVEE, TIFIA) Advance construction Revenue generation/sharing/tolling Vehicle miles traveled fees Global participation Monetization of existing transportation assets Cordon pricing Congestion pricing Franchising Commodity-based hedging against escalation Carbon credit sales Public funds Public–private partnerships Comprehensive development agreements Concession Bond funding Borrowing against future public funding (GARVEE, TIFIA) Advance construction Revenue generation/sharing/tolling Vehicle miles traveled fees Global participation Monetization of existing transportation assets Cordon pricing Congestion pricing Franchising Commodity-based hedging against escalation Carbon credit sales	Political/procurement constraints Environmental issues Public perceptions Right-of-way acquisition Sustainability requirements Owner preferences/biases Political/procurement constraints Environmental issues Public perceptions Right-of-way acquisition Sustainability requirements Owner preferences/biases

Case Study Project Risk Analysis Process

Formal Risk Analysis Areas:
Project Cost Estimate Uncertainty Analysis:
Risk Identification Techniques Used:
Risk Assessment Techniques:
Risk Management Techniques:
Risk Technique Used to Draft Contract:

Case Study Project Procurement Process Summary

Procurement Phase Summary

Required Elements of the Proposal	Evaluated for Award Decision?	Remarks
Qualifications of the project manager		
Qualifications of the designer-of-record		
Past performance record on similar projects		
Proposed schedule		
Proposed schedule milestones		
Lump sum price		
Schedule of values		
Qualifications of the project quality manager		
Qualifications of the design quality manager		
Qualifications of the construction quality manager		
Design quality management plan		
Construction quality assurance plan		
Construction quality control plan		
Independent quality assurance		
Outline specification		

Technical Elements of the Solicitation Package (RFQ/RFP)
Design criteria checklists
Standard design details
Standard guide specifications
Construction testing matrix

Case Study Project Execution Process Summary

Project Planning Phase Summary

Responsibility Allocation for Design Management Tasks	Agency Personnel	Consultant Design Staff	Constructor's Preconstruction Staff	Agency-hired QA/Oversight Consultant
Development of initial budgeting documents				
Preparation of early cost estimates				
Initial cost risk analysis				
Approval of early budgets				
Development of initial project schedules				
Initial schedule risk analysis				
Identification of design alternatives				
Design concept development				
Approval of concepts				
Preparation of project documentation for approvals to proceed				
Development of project funding strategy				
Approval of procurement plan				
Identification of environmental issues				
Identifying required permits and consents				
Identification of ROW requirements/alternatives				
Identification of impacted 3rd parties				
Identification of social issues				
Public meetings				
Public relations planning				

Project Procurement Phase Summary

Responsibility Allocation for Design Management Tasks	Agency Personnel	Consultant Design Staff	Constructor's Preconstruction Staff	Agency-hired QA/Oversight Consultant
Development of predesign cost estimate				
Approval of predesign cost estimate				
Cost risk analysis				
Establishment of project delivery schedule				
Schedule risk analysis				
Selection of project procurement strategy				
Analysis of PDM alternatives				
Procurement risk analysis				
Selection of preferred design concept				
Procurement package development				
Evaluation of qualifications				
Evaluation of technical approach				

Project award decision				
Identification and analysis of funding alternatives				
Obtaining the necessary funding				
Financing risk analysis				
Evaluation of constructor's financing plan				
Plan to gain political buy-in to preferred concept				
Allocating responsibility for permits and consents				
ROW procurement				
Public meetings				
Public relations planning				

Design Phase Summary

Responsibility Allocation for Design Management Tasks	Agency Personnel	Consultant Design Staff	Constructor's Preconstruction Staff	Agency-hired QA/Oversight Consultant
Preparation of cost estimates during design				
Approval of cost estimates during design				
Checking of design quantities				
Approval of payments for design progress				
Approval of design packaging plan				
Approval of design schedule				
Technical review of design deliverables				
Checking of design calculations				
Acceptance of design deliverables				
Review of specifications				
Approval of construction documents				
Scope risk analysis				
Approval of post-award design QA/QC plans				
Development of construction financing plan				
Securing permits and consents				
Coordination with impacted 3rd parties				
Public meetings during design				
Public relations planning				

Construction Phase Summary

Responsibility Allocation for Construction Management Tasks	Agency Personnel	Consultant Design Staff	Constructor's Construction Staff	Agency-hired QA/Oversight Consultant
Checking of pay quantities				
Approval of progress payments for construction progress				
Approval of funding for changes				

Review of construction schedule				
Approval changes to construction schedule				
Technical review of construction shop drawings				
Technical review of construction material submittals				
Routine construction inspection				
Quality control testing				
Establishment of horizontal and vertical control on site				
Verification and acceptance testing				
Approval of construction post-award QA/QC plans				
Technical approval of changes to design				
Execution of construction financing plan				
Approval to changes in financing plan				
Approval of traffic control plans				
Approval of environmental protection plans				
Coordination with impacted 3rd parties				
Obtaining of permits and consents for construction				
Public meetings during construction				
Public relations plan execution				

Quality Management Summary

QA/QC plans: Difference, if any, from the ones used in routine projects.
Use of mandated agency quality management plans: Difference, if any, from the ones used in routine projects.

APPENDIX D

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. Please 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. Please 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. Please 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. Please 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. Please 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 alternative 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. Please rank (1 to 5) the complexity of the following dimensions (Cost, Schedule, Technical, Context, and Financing), with 5 being the most complex. Please 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. Please indicate the overall complexity for each dimension by placing an X on each line below.

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

APPENDIX E

Training Assessment

I. Demographic Information

Employer: ___________________

Age: ☐ 30 or younger ☐ 31–40 ☐ 41–50 ☐ 51–60 ☐ Older than 60

Sex: ☐ Male ☐ Female

Educational Background:

☐ Undergraduate ____________ ☐ Master's Degree _____________ ☐ Ph.D. ______________

What is your job title? ____

Briefly explain your current duties/responsibilities:

____

____

____

How many years have you worked in transportation project management?

☐ Less than 5 years ☐ 6–10 years ☐ 11–15 years ☐ 16–20 years ☐ More than 21 years

II. Perceptions About the Modules Training Program (Modules 0–5)

Please assign a value from 1 to 5 to each statement, where 5 = Totally agree, 4 = Agree, 3 = Neither agree nor disagree, 2 = Disagree, and 1 = Totally disagree.

	Scale	
1.	5 4 3 2 1	The module program provided valuable information.
2.	5 4 3 2 1	The module program was easy to follow and understand.
3.	5 4 3 2 1	The module program has a good balance between theory and exercises.
4.	5 4 3 2 1	The exercises were helpful in applying the theory presented.
5.	5 4 3 2 1	I would recommend the module program to my peers.

Was the delivery method appropriate? ☐ Yes ☐ No Explain: ____

____

Was the level of information presented appropriate? ☐ Yes ☐ No Explain: ______________________________

____

What did you like the most about the module training program?

____

____

What did you like the least about the module training program?

____

____

What would you change from the module training program?

____

____

III. Perceptions About the 5D Project Management Model (5DPM)

Please assign a value from 1 to 5 to each statement, where 5 = Totally agree, 4 = Agree, 3 = Neither agree nor disagree, 2 = Disagree, and 1 = Totally disagree.

	Scale	
1.	5 4 3 2 1	The 5DPM model advances the state of project delivery.
2.	5 4 3 2 1	Based on my experience, the finance dimension adds to project delivery theory.
3.	5 4 3 2 1	Based on my experience, the context dimension adds to project delivery theory.
4.	5 4 3 2 1	The 5DPM model is applicable to future projects in my DOT.

Other Comments:

____

____

____

____

Contact Information (Optional):

Name: ______________________________________

Email: ______________________________________

Phone number: _______________________________

Related SHRP 2 Research

Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects (R03)

Performance Specifications for Rapid Highway Renewal (R07)

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)