9-7-2011

Defining Complex Project Management of Large U.S. Transportation Projects: A Comparative Case Study Analysis

John Owens
Kiewit Underground

Junyong Ahn
Iowa State University

Jennifer S. Shane
Iowa State University, jsshane@iastate.edu

See next page for additional authors

Defining Complex Project Management of Large U.S. Transportation Projects: A Comparative Case Study Analysis

Abstract
The management of complex transportation projects requires a fundamental change in how they are approached. The traditional methodology for managing cost, schedule, and design, on transportation projects is not adequate for complex projects.A five-dimensional model has been developed adding context and finance, which have previously been regarded merely as external risks. The five-dimensional model has been developed from an extensive literature search pertaining to the management of complex transportation projects and provides a framework for mapping the complexity of projects. The main purpose of this research is to present results found on complex transportation projects that illustrate a new type of management approach for project managers. The information gathered from these case studies can be used to examine similarities to infer common sources of complexity, and mapping of each project facilitates resource allocation decisions based on these commonalities.

Keywords
Chemical & Biological Engineering, Complex projects, transportation, project management, context, finance

Disciplines
Civil Engineering | Construction Engineering and Management | Environmental Engineering

Comments
This is a manuscript of an article from *Public Works Management and Policy*, 17(2012): 170-188. doi: 10.1177/1087724X11419306. Posted with permission.

Authors
John Owens, Junyong Ahn, Jennifer S. Shane, Kelly C. Strong, and Douglas D. Gransberg

Owens, J., J. Ahn, J.S. Shane, K.C. Strong, D.D. Gransberg, "Defining Complex Project Management of Large US Transportation Projects: A Comparative Case Study Analysis," Public Works Management and Policy, Vol. 16 (4), October 2011, pp.234.1-10.

Defining Complex Project Management of Large US Transportation Projects:

A Comparative Case Study Analysis

John Owens, Junyong Ahn, Ph.D., Jennifer S. Shane, Ph.D., Kelly C. Strong, Ph.D., Douglas D. Gransberg, Ph.D., PE

ABSTRACT

The management of complex transportation projects requires a fundamental change in how they are approached. The traditional methodology for managing cost, schedule, and design, on transportation projects, is not adequate for complex projects. A five-dimensional model has been developed adding context and finance, which have previously been regarded merely as external risks. The five-dimensional model has been developed from an extensive literature search pertaining to the management of complex transportation projects and provides a framework for mapping the complexity of projects. The main purpose of this research is to present results found on complex transportation projects that illustrate a new type of management approach for project managers. The information gathered from these case studies can be used to examine similarities in order to infer common sources of complexity, and mapping of each project facilitates resource allocation decisions based on these commonalities.

Keywords: Complex projects; transportation; project management; context; finance

INTRODUCTION

Traditional transportation project management models are based on the integration of three areas (cost, schedule, and design) that must be optimized to deliver the expected scope of work (Marshall and Rousey, 2009). The need to address current project management practices has evolved from traditional methods that were developed during the expansion of the U.S.

This is a manuscript of an article from *Public Works Management & Policy, 17(2011): 170. doi: 10.1177/1087724X11419306. Posted with permission.*

transportation infrastructure. However, transportation projects now involve replacing, instead of creating, the existing transportation infrastructure. The 1990's brought the demand from public owners to deliver public infrastructure projects faster and with more control over cost (Gransberg et al., 2006; Lopez et al., 2008; Sillars, 2009), further directing the need for the new thoughts on project management. The problem with traditional project management in complex projects is summarized in the final report of NCHRP Project 20-69: *Guidance for Transportation Project Management* (2009). The study found that projects over $5 million in construction costs were under budget only 20 percent of the time and delivered on time only 35 percent of the time. The study also found that the majority of the issues relating to cost and schedule issues can be solved using effective management protocols and procedures. The intent of the study was to demonstrate that project managers need to be trained to think of projects as integrated systems (Marshall and Rousey, 2009).

The Channel Tunnel (Chunnel) project is a good example showing that project management based on just the three traditional areas (cost, schedule, and design) are not enough for complex project management. The Chunnel project, an underground tunnel connecting France and England, required many other aspects of project management than the three traditional areas, such as the cooperation of two national governments, permission from bankers for the funding of the project, private financing, and partnering with numerous stakeholders. Though the project was completed, it was over budget and late with more than twice the average cost escalation of tunnels and bridges (Flyvbjerg et al., 2004). In fact, the engineering was less complex than the context in which the construction took place. Highly sophisticated project management procedures were required to complete this complex project.

Another example of the changing nature of project management for complex projects can be found in the Central/Artery Tunnel project in Boston (the “Big Dig”). The project management team successfully partnered with local businesses, public service providers, and communities to mitigate the impact of the project on local residents (Dimino, 2004), but the failure to properly manage funding and financing complexities lead to massive cost overruns (McManamy, 2004) and the externalizing of risk factors (assuming they were beyond the control of the project team) during the planning phase led to lingering problems on the project (Lyons, 2008). Also, the report from the Committee for Review of the Project Management Practices Employed on the Boston Central Artery/Tunnel Project (2003) stated that despite an emphasis on reaching the milestones on time, the project did not meet scheduled targets, which led to reduced public confidence in CA/T management.

Project management is evolving into a different form where 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). Winter and Smith (2006) developed an excellent conceptual framework and synthesizing field study of the changing nature of project management entitled: “Rethinking Project Management.” 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 developed framework called “Five New Directions of Thought” was to define the difference between routine project management and the management of complex projects in the 21st century. One of the new directions indicates recognizing that projects are influenced by more external agents than just technical engineering and construction means and methods.

Therefore, project managers on complex projects now need to be able to optimize the available resources (cost and schedule) with the technical performance needs of the project (design) while operating under both known and unknown constraints (context), all while accommodating the requirements of new financing partners and funding models (financing). This new model goes beyond thinking about contextual elements as external risks and considers them a direct, "controllable" impact associated with the project. Project managers should accept them as an integral part that requires effective management practices similar to the traditional cost, schedule, and design areas. In addition, with the advent of new financing methods and budgetary cuts, project managers can no longer assume that program funding will be sufficient and must consider financing a crucial piece of effective project management.

OBJECTIVE

Based on the analysis of existing techniques and sources of complexity, it is the intent of the research to conduct case studies for ongoing or completed large US complex transportation projects. For the purpose of this research, the definition of complex projects involves a minimum of four out of the five areas experiencing complex management challenges. The focus of the case studies is to determine the issues with the management of complex projects and examine commonalities between the projects. In addition, the goal is to map these projects based on numerical values attributed to each management area in an attempt to provide upper level directors a method to examine upcoming projects and allocate resources accordingly based on the anticipated complexity of each area.

The first step in this research is to review literature based on complex project management and identify the factors contributing to complexity for each of the five areas. The literature review is conducted as a two-step process. The first step consists of synthesizing the information gathered during the literature review to identify common success factors and universal effective practices that can be applied on virtually all projects. The second step is to categorize those success factors and effective practices in each of the five areas.

The focus of the remaining research is to take the existing project management practices and develop case study interviews on the defined sources of complexity in order to identify commonalities in the management of complex transportation projects. The results of the case studies show that there are similar sources of complexity found in each case. In addition, it is possible to map these projects for potential use by upper management to make resource allocation decisions and redefine how their organization views complex transportation projects. Complex project management is evolving and the following findings attempt to convey a methodology for considering all elements related to complex project management in a manner that can be readily repeated and used throughout the project management community.

LITERATURE REVIEW

A literature review was conducted to analyze the current state of knowledge and practice pertaining to complex project management of transportation projects and determine what factors contribute to complexity within each of the five areas. As a result, the factors contributing to complexity within each area are determined and organized under categories based on similarities. Each factor can independently create complexity. However, it is important to note that the dynamic interaction between these factors is the true source of complexity. The sources of complexity for each area are as follows (SHRP2 R10 Phase I Report).

- Cost factors: Contingency, uncertainty, estimates, cost allocation, control, optimization, incentive, material, and transit user
- Schedule factors: Time, risk, milestones, control, optimization, resource availability, visualization, and system/software
- Design factors: Scope, internal structure, prequalification, warranties, disputes, delivery method, review/analysis, method, existing conditions, quality, safety/health, optimization, climate, technology usage, intelligent transportation systems, automation
- Context factors: 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, environmental limitations, procedural law, local acceptance, global economics, incidents, weather, force majeure
- Finance factors: Legislative, uniformity, transition, financial training for PM , federal, state, bond, borrowing against future, advanced construction, revenue generation, vehicle miles fees, cordon/congestion pricing, monetization of existing assets, franchising, carbon credit sales, public-private-partnership/concessions, commodity-based hedging, global participation

These factors have been established as major contributors to complexity on transportation projects through extensive literature review and each factor is mentioned as a source of complexity by many researchers. For example, Miller and Lantz (2010) argued that scoping can largely affect a project's success and presented scoping problems such as lack of a clear purpose statement from the planning process; incongruence between planning cost estimates and scoping estimates; scoping of projects not having full construction funding; insufficient participation from outside agencies; and insufficient documentation of follow-up commitments fulfilled after the scope is established.

A case study concerning public collaboration in transportation (Majumdar et al., 2009) showed the importance of the relationship between public/local community and project participants. The case study presented evidence that there are structural flaws even in a well designed plan of interaction. When such flaws combined with lack of understanding of local history, the establishment of a meaningful partnership with the local community can be interrupted (Majumdar et al., 2009).

Migliaccio et al. (2008) investigated complexity of implementing new project delivery methods, especially for design-build, and developed a framework to address organizational change to using alternative project delivery methods. From the investigation, barriers to and facilitation of implementation of alternative project delivery systems are presented. Among them, comprehensive legislative authority for changing the delivery and finance strategy and organizational implementation plans are listed to facilitate the change.

Based on the findings in the literature review, the case study interviews were conducted to identify the nature of complexity within each management area. Based on the results of the case study interviews, the factors that contribute to the complexity for the project will be determined and discussed.

METHODOLOGY

Based on the overall research process, a protocol has been developed for conducting the research on complex transportation projects as shown in Figure 1.

From the results of the literature review, an interview questionnaire was developed that poses both qualitative and quantitative questions. The general flow of the interview is to discuss the factors that contribute to complexity within each management area and compare the complexity of the particular category against other projects that have been worked on by the participant. The discussions between the interviewer and interviewee serve as a basis so the interviewee has an understanding of the complexity of the management area and can ultimately assign a numerical score for the specific area at the end of each section of the survey.

Once the structured interview questionnaire was developed, the case study interview protocol was pilot tested. The research team pilot tested the interview questionnaire so that necessary changes could be marked as the pilot was conducted (Gilham 2008). Case studies needed to be identified as shown in Figure 1. The case studies were drawn from the Federal Highway Administration (FHWA) major project website. There are approximately 85 projects in the FHWA major project website. A one hour phone interview with the FHWA major projects team leader resulted in his recommendation of the five projects chosen for the initial case studies. Interviews were conducted with project leaders knowledgeable about all phases of the project. Interviews took place March-June 2010.

Before the interviews were conducted, potential case studies were narrowed down based on geographic dispersion, project delivery method, project size, and availability of project expert. Case studies were selected that represent the definition of complex transportation projects outlined in the objective section. A total of five cases were selected and confirmed by the major projects team leader at FHWA.

Once the case studies are selected, the interview process was the main focus of the next step as shown in Figure 1. The interview process was conducted over the phone with the lead owner's representative from each of the case study projects. The lead owner's representative was familiar with all aspects of the project and had access to all required information to complete the case study interview. Before the scheduled interview, the survey was sent out so that the participant could review and familiarize themselves with the study (Gilham 2008). The bulk of the information was gathered during this stage, making it crucial that the interview was structured and comprehensive. In addition to the case study interview, archival information was collected from public documents such as project newsletters, FHWA and DOT reports, and project websites.

The last step in the research protocol was data verification. To ensure all of the information gathered was accurate, the use of a summary section and follow up verification were conducted. The summary section allowed the researcher to transfer the scores from each area and assisted the interviewee in examining all of the areas together and verified that their scoring accurately reflected the intent of the participant. To double check that the interviewer obtained accurate responses from the interviewee, the interviewer recorded all of the qualitative information and summarized the data on a completed survey. The completed survey was then sent to the participant so that all of the information could be confirmed or corrected if necessary.

CASE STUDIES

Five projects were selected to serve as case studies for analyzing the project complexity in each of the five management areas of the model. The five case studies are summarized in Table 1 with pertinent background information.

Case Study Comparison Summary

In order to compare the case study projects and analyze the similarities found between them, issues identified on multiple projects are presented within each area in this section in an attempt to identify the most common management challenges encountered on complex transportation projects. Case study analysis used pattern matching to create a data array of similar issues and responses to them. Patterns in the case study data were independently evaluated by the five members of the research team. If there was agreement between 4 of 5 members of the research team, the results were considered valid. If there was disagreement among the results, an attempt was made to clarify meaning and resolve different interpretations. If no agreement could be reached, the result was dropped from the analysis. There were 18 identifiable results from the five researchers, but the final data array contained only 13 common findings based on concurrence of the research team.

Cost

The majority of the issues contributing to cost complexity are found in most of the projects, two of which appear in all five projects and a few overlap, as shown in Table 2. One of the major findings concerning cost complexity is that all five projects used acceleration of the schedule. Some project teams made the decision to accelerate the schedule based on transit user benefits, while others simply wanted to open the project faster to reduce road user costs, and others had a specific event (e.g. the Olympic games) imposing completion deadlines. All but one project noted that the type of contract affected the way the costs were managed for their projects.

Considering that none of the projects were performed under the traditional design-bid-build (DBB) methodology and that many of these owners had never attempted a project using a different procurement method, this finding seems plausible.

The other source of complexity found on all of the projects was the issue of estimates. However, each project did not have the same estimate issues. The problems found with the estimates were: conducted with little design completed, outdated, originally performed for a longer time period, scope change leading to estimate growth, and high estimates limiting the scope.

The other four sources were only found on a few of the projects. One issue related to estimates is the risk associated with the changing scope seen on two projects. Both of these projects added scope that had to be coordinated and funded in some manner. Material issues were not a major source of complexity with the exception of the I-15 project that physically could not obtain enough materials, but clauses were built into the contracts for specific material escalation. Direct external agency cost risk was prevalent on two of the projects. The TH 212 project encountered significant utility challenges and the Warwick project dealt with air, rail, and highway agencies. Both of these agencies were mentioned under the cost area due to the potential impact negotiations had, or could have had, on the cost of the projects. The last challenge seen on multiple projects was the high focus on cost control. With the large and sometimes very restrictive budgets, three projects used team resources that were specifically assigned to cost controls.

Schedule

Relating to the cost complexity is the tight timeline issue apparent on all five projects, as shown in Table 3. Acceleration was discussed in the cost area and the basis for the acceleration is the ambitious schedules for the studied projects. The expected timelines are consistent with the use of the alternate delivery methods used for the projects. Each project participant stated that the timeline was a critical component adding to the schedule complexity.

Considering that the timelines were accelerated, the external agency risk contributed to the schedule complexity. Schedule risk was found for each project due to external issues such as utility coordination, environmental clearances, land acquisition, and inclement weather.

Another source of complexity seen was the type of scheduling technology utilized. Four of the five projects required cost and resource loaded schedules. These schedules were monitored and verified for control and payment purposes on some of the projects. In addition to these schedules being used for control and verification purposes, separate teams designated to schedule control were used on some of the projects. In some instances, schedule experts were hired as well.

Control also leads into the milestone prioritization complexity issue. Three of the projects mentioned increment milestones as a challenge that needed to be managed even though the schedule was primarily the responsibility of the contractor through the alternative contracting approaches. The last source of complexity seen was the ability to alter the schedule. One project encountered issues with acceleration due to payment restrictions while the other stated that the owner was willing to burn contingency to accelerate the schedule.

Design

No issue was found in all five of the projects for the design complexity, as shown in Table 4. The delivery method of the projects has been mentioned already, but it is more apparent in this area. Four of the projects were conducted using design-build (DB) while the fifth was performed using Construction Management at Risk (CM@R). One source of complexity found on four of the projects was that the delivery method impacted how the contract was formed. Since this was the first time some of these owners had used alternate delivery methods, this source seems apparent. This finding is validated by the finding that the Minnesota Department of Transportation (MnDOT) has used alternate delivery methods in the past, and the TH 212 was not impacted by the contract formation of a different delivery method. Therefore, it appears that innovation (trying something new) is in itself a source of complexity that may dissipate over time as the innovation becomes institutionalized. Some of the common issues with the contract formation were determining how the contract was viewed by all of the parties, delegation of responsibilities for different portions of the project (e.g. quality control), and the disparity between confidential and public information.

The dispute resolution process was another issue arising in four of the projects. Once again, MnDOT's familiarity with DB may have reduced the complexity with the dispute resolution process. All four participants stated that the dispute process was more complex with new methods being implemented, dispute review boards being created, and dispute meetings occurring more frequently depending on the project.

Two other sources that were directly affected by the contract language were quality control issues and the design process. Since the design-builder was ultimately responsible for the quality and design, the owner's had to develop new methods for monitoring these processes. The major focus of the quality control efforts were figuring out ways to analyze quality problems, ensuring quality was not sacrificed because of the accelerated schedules, and using oversight programs to verify the projects were being constructed adequately. The design process also limited the direct impact the owner's had on the physical design of the project. Many of the project's designs encountered extensive limitations through existing conditions making the designs complex. Owners also had to create ways to monitor the design quality and determine how to conduct value engineering (VE) and constructability review (CR) sessions to verify the design adhered to the standards set forth.

Internally, the selected delivery method also affected the structure of the owner's organization on three of the projects. Two of the projects created entirely different project teams with different roles and power to make project decisions. The third project noted their structure caused issues because of multiple owners and how the project was viewed by each. All five of the projects studied were very large in nature and had immense scopes. The sixth source found in four of the projects was scope issues. Some had scope creep and others did not, but four project teams did agree that the scope of the project caused management complexity because of size, delivery type, and budget constraint issues.

Transit technology implementation is the last source found on three of the projects and added to the complexity of these projects. It was the first time that it was used on the I-15 project and the I-64 used it for extensive rerouting of traffic on surrounding routes due to the full shutdowns of the highway. Both of these projects noted that the transit technology added to the overall complexity of the design area.

Context

The context area clearly has more complexity sources than any of the others, as noted in Table 5. Some of the defined factors have been aggregated based on impact and management complexity to condense the results of the context area. Twelve similar issues were found on the projects and six of those were found on all five of the projects studied. Political issues are the first source occurring throughout all of the projects. Project participants noted that political involvement was very apparent and could be either positive or negative. In some instances the politicians were driving the project and expectations needed to be kept in check while in others they were trying to halt construction.

The second source appearing in all five projects is titled local group's impact which is comprised of the public, multiple area jurisdictions, and local agency challenges. The public was one factor that needed to be managed due to project expectations, approvals, design decisions, and overall apprehension. Multiple jurisdictions and local agencies were also seen on some of the projects that required management resources. Also included in the local group's impact source are social, demographic, and project acceptance factors. These were not seen on all of the projects, but are included in this source because they provided similar management challenges since they are highly correlated with the public aspect.

Media and marketing control is another source that was found on all five projects. Considering the size and cost of the projects studied, the marketing plans had to be comprehensive. All five of the projects used some form of a marketing plan and controlled the information flow to the media in some fashion. Some projects utilized marketing consultants while others did not.

Utilities have already been discussed concerning their potential impact on the cost, schedule, and design of the projects. The scope of all five projects encountered many utility relocation and coordination challenges. Some of the projects noted that the condensed timeframe increased the amount of resources needed to deal with utility challenges.

Another source of complexity found on all of the projects was environmental issues. This source includes a variety of issues found through the case studies including hazard remediation, wetlands replacement, environmental clearances, extensive environmental impact statements, joint permits, use of sustainable/recycled materials, and general environmental impact concerns. Not all of the listed environmental issues appeared on every project, but it is safe to conclude that every project met environmental limitations that required management resources.

The last source of complexity found on all of the projects studied is the impact the project had on land changes. This source includes elements such as land acquisition through condemnation and eminent domain, growth inducement, rezoning, and changing land values. Once again it is important to note that not all of these issues were prevalent on all of the projects, but the research draws a link between complex transportation projects and significant local land impacts.

The remaining six sources of complexity were not seen on all of the studied projects, but provided management complexity. A summary of the common issues found is presented below:

- Creation of new and alteration of existing emergency routes
- Extensive traffic control plans that include techniques such as retiming of signals, visualization techniques, and overall rerouting of traffic
- Legislative approval for alternate delivery method use and legal limitations that were altered in order for the selected delivery method to be successful
- Inclement weather causing delays
- Intermodal incorporation
- Business access programs

The context complexity described above has drawn many commonalities between the projects, which are expected with the immense amount of external factors facing the management teams for the case study projects. Future complex projects should take note of the similarities found within this area.

Financing

Of the five studied projects, there was no single financial issue found on all of the projects, as noted in Table 6. One source identified in four of the projects was the issue of multiple types of financing. Considering the size of the projects and the financial requirements, the project teams noted that many different types of financing were necessary to construct the project. Each project did not use the same kinds of financing, but each participant stated that managing the different types of financing added to the project management complexity. Financing is related to project management and project delivery based on the speed of delivery and related cash flow issues. When using design-build care needs to be taken to ensure project funds are available to meet progress payment requirements.

The other source that appeared in four of the projects was the use of commodity based hedging. Through the use of alternative delivery methods the material prices were essentially locked in once the contract were signed. This source did not necessarily add to the complexity, but it is worth pointing out that this technique was used whether or not it was intentionally planned.

The rest of the sources were seen on three or fewer projects according to Table 6. Three of the projects used bonds to match federal funds and some of the projects ran into complexity issues such as obtaining the bonds and performing sensitivity analyses to provide adequate coverage ratios. Obtaining financing was also found to be hindered due to legislative limitations. Limitations found on the projects included obtaining authorization that the project was federally eligible and restrictions on how the funding could be spent. Another limitation encountered on two projects was the ability of the owner to pay the contractor for work performed in advance of the contract. Two sources that are similar to each other are the requirement of financial plans and the use of financial professionals. Financial plans were used as well as financial professionals such as Chief Financial Officers and financial controllers on a few of the projects as shown in Table 6. The last source occurs only on those projects using revenue stream financing. The issues between the projects were different, but they were both based on the premise that the projected revenue needed to be carefully calculated.

Financing is related to project delivery and project management

Case Study Results

The following list summarizes the sources of complexity that were found in at least four out of the five projects. The intent is to serve as a comprehensive list of the most probable complexity sources for project managers planning future transportation projects anticipated to be of a complex nature:

- Contract type changing cost methods
- Balance between incentives, optimization, acceleration, and transit user benefits
- Estimate issues
- Tight timeline
- External agency risk
- Resource & cost loaded schedules
- Delivery method impacting contract formation
- Complex dispute resolution process
- Quality control issues
- Design process, design quality, existing conditions, VE's & CR's
- Scope issues
- Political issues
- Local groups impact
- Media and marketing control
- Utility coordination
- Environmental issues
- Land changes & impacts
- Multiple types of financing
- Use of commodity based hedging

The factors listed above merely serve as a starting point and display the most prominent sources found through this research. When faced with complex projects, project management professionals should brainstorm and analyze potential complex issues that may arise on a given project.

Complex projects have the three traditional dimensions of cost, schedule, and technical (scope) control, but also have extraordinary issues related to finance and context that must also be controlled by the project manager. The difficulties in assessing the resource needs of a five dimensional model of project management can be simplified by utilizing graphic representations of complexity. The following section presents a radar diagram combining the summary results of all of the studied cases in an attempt to analyze and compare the complexity ratings of all five projects in a quantitative fashion.

Complexity Score Comparisons

The radar diagram presented in Figure 2 displays all of the complexity scores of each of the five project management dimensions for the projects studied. The project experts interviewed during the case studies were asked to rate their projects on each of the five project management dimensions using a scale of 10 to 100. The bottom of the scale is anchored by a score of ten under the assumption that no project can have "zero" complexity on any of the five dimensions, while the top of the scale is denoted by a score of 100, indicating that the project was conceivable as complex as possible in that dimension. By comparing the area of each complexity diagram, unique project needs (project success factors, team skills, resource commitments, risk strategies) can be identified. The main use for this diagram would be for an upper level director to compare the complexity scores of a set of upcoming projects and allocate resources based on the expected complexities for the management areas.

According to the diagram all of the projects studied were deemed to be complex for all of the management areas based on an average project receiving a score of 55 on all areas, with the exception of the design (technical) complexity for the E-470 project. Each project has areas where the complexity is greater than other areas and the resources should be allocated based on these results. The I-15 project as a whole appears to be the most complex based on the overall area of its graph. The other projects have specific dimensions that are higher than others and resource allocations could be justified with the project characteristics identified. For example, the Warwick and E-470 have higher financing scores which follow the financing methods used for these projects. The Warwick project used five different financing sources and the E-470 project used tolls, bonds, public license fees, and borrowing against future funding. Comparing these financing methods against the financing of the other projects validates the higher scores for these projects regarding the financing complexity. Each management area and project follows a similar comparison depending on the level of analysis and directors will be able to compare characteristics of their projects with those found on the studied projects to implement effective management practices.

One of the other objectives of this research is to facilitate resource allocation based on the complexity of individual projects. Each project tends to lean towards one management area being more complex. Ideally, during the planning stages the project planners should use this concept to allocate the resources, specifically technical expertise of project team members, according to the anticipated complexity of each management area.

CONCLUSIONS

The goal of this study was to identify sources of complexity through case studies and analyze each management area for resource allocation purposes. Based on the complexity factors suggested in the SHRP2 R10 project, case studies were conducted through surveys and interviews on current and completed projects. Through the interview process, each management area was numerically scored and verified, then, it was analyzed based on common issues found in the studied projects. The overall intent of the project was to provide project managers and upper level directors a comprehensive look at the management of complex transportation projects and provide a conceptual methodology focused on the transition of the project management field.

Even though it is impossible to create a list that would involve every possible source of complexity, the results presented through the case studies serve as a starting point for comparisons and potential management strategies. Project managers can no longer think of the separate elements of a project as merely assigned risks (e.g. “owner’s” risk, “contractor’s” risk, “designer’s” risk, “financers” risk, etc.). The project manager of modern complex projects must approach the challenges of each project utilizing an integrated, team-based approach relying on proactive planning and communication among all project partners (Shane et al., forthcoming). This can best be accomplished by assembling an owner-driven team early in the project life cycle and choosing a delivery method and innovative contract approach that maximizes the probability of achieving key project success objectives.

The factors that contribute to management complexity and the most prevalent practical problems are presented. They contain sources from each management area concluding that all of the five areas studied in this project have issues that span across multiple projects. Breaking the list down even further, the studied complex projects are constrained by accelerated timelines causing cost, design, and quality control issues. In addition to these factors found in the traditional management areas (cost, schedule, and design), external forces caused by local groups and multiple types of financing are primary sources of complexity found in the additional management areas (context and financing). Although many more sources of complexity have been found throughout the research, the above factors seem to be the driving forces behind the management of complex transportation projects.

The radar diagram presented serves as a method for upper level directors to evaluate upcoming projects and allocate resources based on the anticipated complexity of each management area. Comparing the results of the radar diagrams to the analysis of the interview discussions, the results appear to be consistent with the management challenges faced on each individual project. This leads to the conclusion that the complexity scoring process is a task that can be performed within an owner's organization in order to allocate resources based on the predicted results. Once the management areas have been compared between projects, directors should have the information necessary to allocate professionals with specific skill sets to the complexity factors that require that type of experience.

The results in this study serve as a basis for how complex transportation projects should be viewed in the future. Reiterating, the aim of the project was to be as comprehensive as possible in providing an overview in the management for complex projects, but it is likely that other sources of complexity may arise on projects that have not been mentioned, further requiring additional management strategies.

The research was targeted, examining the unique characteristics of major, complex transportation projects. There are only 85 such projects in the FHWA major projects database, Therefore, results of the research may not be generalizable to all public works projects. However, many of the factors discussed may prove useful to upper level managers in delivering public works projects of moderate to significant complexity.

FUNDING

This work was partially supported by the Strategic Highway Research Program 2, Transportation Research Board of the National Academies [Project No. R10].

REFERENCES

Atkinson, R. (1999). “Project management: cost, time and quality, two best guesses and a phenomenon, it’s time to accept other success criteria,” *International Journal of Project Management*, 17(6), December, pp. 337–342.

Cleland, D. and Ireland, L. (2002). Project Management: Strategic Design and Implementation, McGraw-Hill Professional, ISBN-10: 0071393102.

Committee for Review of the Project Management Practices Employed on the Boston Central Artery/Tunnel ("Big Dig") Project (2003). “Completing the "Big Dig": Managing the Final Stages of Boston's Central Artery/Tunnel Project,” National Research Council, National Academy of Engineering, ISBN: 0-309-56657-6, 60 pages.

Dimino, R. (2004). “Partnerships Vital to Project's Success,” *Public Works*, 135(10), pp. 62–66.

Flyvbjerg, B., Holm, M. K. S., and Buhl, S. L. (2004). “What Causes Cost Overrun in Transportation Infrastructure Projects?” *Transportation Reviews,* 24(1), January, pp. 3–18.

Gilham, B. (2008). Small-Scale Social Survey Methods, London and New York: Continuum, ISBN: 9780826496300.

Gransberg, D., Koch, J., and Molenaar, K. (2006). Preparing for Design-Build Projects: A Primer for Owners, Engineers, and Contractors, American Society of Civil Engineers, ISBN-10: 0784408289.

Lopez del Puerto, C., Gransberg, D., and Shane, J. (2008). “Comparative Analysis of Owner Goals for Design/Build Projects,” *Journal of Management in Engineering,* ASCE, 24(1), pp. 32–39.

Lyons, J. (2008). “Objectively Assessing Risk in a Complex World,” *Leadership and Management in Engineering,* 8(4), pp. 231–254.

Majumdar, S. R., Moynihan, C., and Pierce, J. (2009). “Public Collaboration in Transportation: A Case Study,” *Journal of Public Works Management & Policy,* 14(1), pp. 55–80.

Marshall, K. R. and Rousey, S. (2009). Guidance for Transportation Project Management, NCHRP Web-Only Document 139, Transportation Research Board ,National Academies, Washington, D.C., 217 pp.

McManamy, R. (2004). “Dirt Flying as Boston's Big Dig Winds Down,” *Public Works*, 135(7), pp. 80.

Migliaccio, G. C., Gibson, Jr. G. E., and O’Connor, J. T. (2008). “Changing Project Delivery Strategy: An Implementation Framework,” *Journal of Public Works Management & Policy,* 12(3), pp. 483 – 502.

Miller, J. S. and Lantz Jr., K. E. (2010). “Options for Improving Transportation Project Scoping,” *Journal of Public Works Management & Policy*, 14(4), pp. 332–350.

Shane, J., Strong, K., and Gransberg, D. (2010). Project Management Strategies for Complex Projects, SHRP2 R10 Phase I Interim Report, Transportation Research Board, National Academies, Washington, D.C., 137pp.

Shane, J., Strong, K., and Gransberg, D. (forthcoming). "A Multidimensional Model of Project Leadership," *Leadership and Management in Engineering*, American Society of Civil Engineers.

Sillars, D. N. (2009). "Development of Decision Model for Selection of Appropriate Timely Delivery Techniques for Highway Projects," *Transportation Research Record 2098*, pp. 18–28.

Winter, M. and Smith, C. (2006). "Rethinking Project Management," EPSRC Network 2004-2006, Final Report, EPSRC, Manchester, UK.

Table 1. Case Study Selection and Background Information

Project	#1 (E-470,	#2 (TH-212	#3 (I-15	#4 (Warwick	#5 (I-64

	Segment 4)	DB)	Reconstruction)	Intermodal)	Reconstruction)
Location	Colorado	Minnesota	Utah	Rhode Island	Missouri
Type	New 4-lane tollway	New 4-lane alignment	Highway reconstruction	Multi-modal facility	Highway reconstruction
Delivery Method	Design-Build	Design-Build	Design-Build	Construction Management at Risk (CM@R)	Design-Build
Cost	$250M	$238M	$1.6B	$267	$535M
Timeline	~3 years	~3 years	~4 years	~4 years	~2.5 years
Major sources of complexity	-Multiple financing types	-Accelerated timeline -Depressed roadway	-Accelerated timeline -Resource availability -Size of project	-Multiple financing types -Stakeholder/Owner coordination	-Owner's internal structure -Existing structural limitations

Table 2. Project Similarities Contributing to Cost Complexity

Issue	E-470	TH 212	I-15	Warwick	I-64
Contract type changed cost modeling methods	X		X	X	X
Incentives, optimization, acceleration, transit user benefits	X	X	X	X	X
Material issues		X	X	X	
External agency risk		X		X	
Estimate issues	X	X	X	X	X
High focus on control			X	X	X
Risk due to changing scope				X	X

Table 3. Project Similarities Contributing to Schedule Complexity

Issue	E-470	TH 212	I-15	Warwick	I-64
Tight timeline	X	X	X	X	X
External agency risk	X	X	X	X	X
Resource & cost loaded schedules		X	X	X	X
Control & verification issues			X	X	X
Milestone prioritization	X		X		X
Schedule alteration		X	X		

Table 4. Project Similarities Contributing to Technical Complexity

Issue	E-470	TH 212	I-15	Warwick	I-64
Delivery method impacted contract formation	X		X	X	X
Complex dispute resolution process	X		X	X	X
Quality control issues	X	X	X		X
Design process, quality, existing conditions, VE’s & CR’s		X	X	X	X
Delivery method altered internal structure			X	X	X
Scope issues		X	X	X	X
Transit technology implementation	X		X		X

Table 5. Project Similarities Contributing to Context Complexity

Issue	E-470	TH 212	I-15	Warwick	I-64
Political issues	X	X	X	X	X
Local groups impact	X	X	X	X	X
Media and marketing control	X	X	X	X	X
Utility coordination	X	X	X	X	X
Environmental issues	X	X	X	X	X
Land changes & impacts	X	X	X	X	X
Emergency route impacts	X		X		X
Traffic management		X	X		X
Legal & legislative barriers		X	X		X
Inclement weather	X	X			X
Intermodal challenges	X		X	X	
Program impacts			X		X

Table 6. Project Similarities Contributing to Financing Complexity

Issue	E-470	TH 212	I-15	Warwick	I-64
Multiple types	X		X	X	X
Requirement of financial plans	X		X		
Commodity based hedging		X	X	X	X
Ability to pay		X	X		
Financial professionals			X	X	
Bond issues	X			X	X
Legislative limitations			X	X	
Revenue stream concerns	X			X	

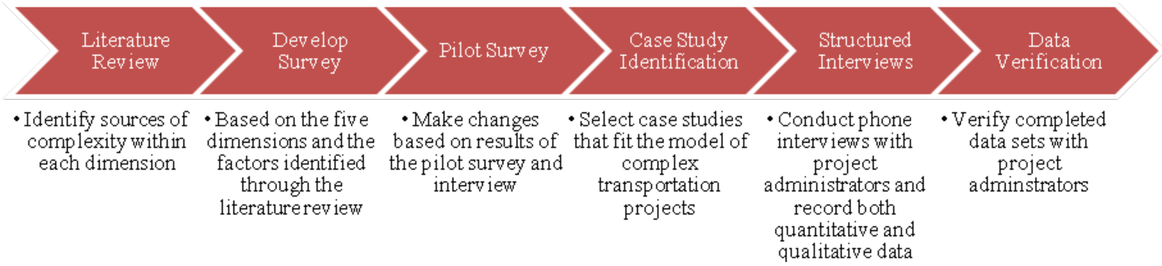

Figure 1. Research Protocol

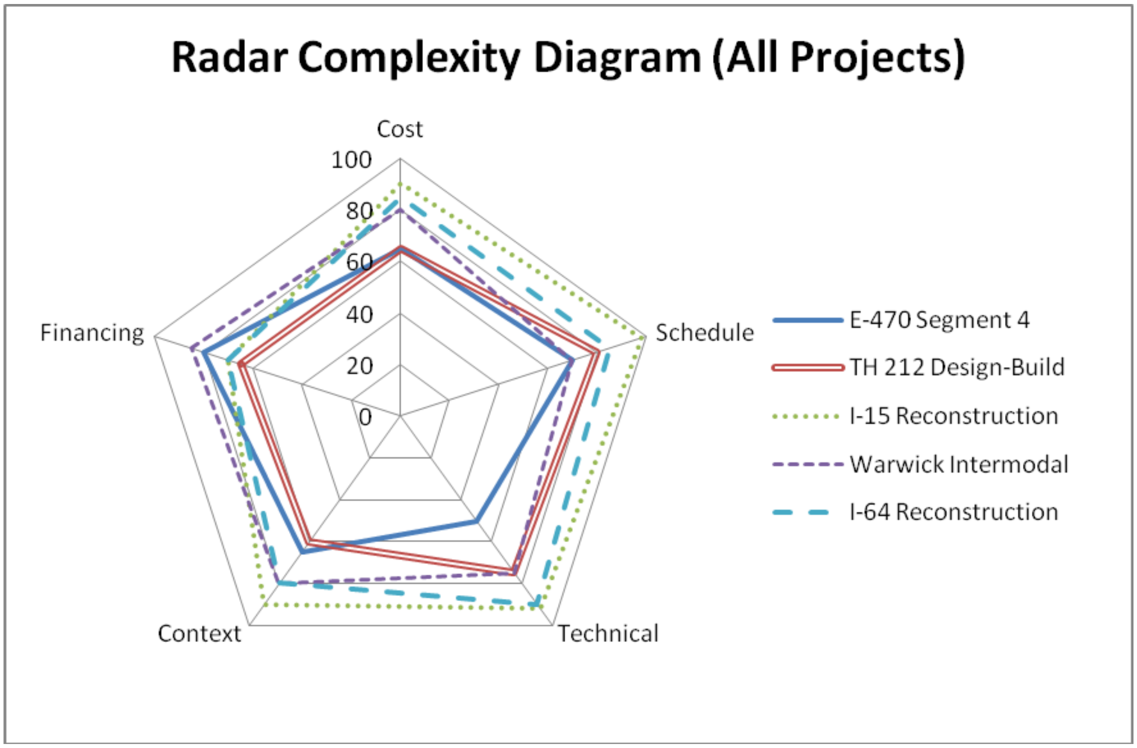

Figure 2. Radar Complexity Diagram