

Project Management Tools for Design-Bid-Build Mega-Projects

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Large, complex transportation projects have recently been delivered using alternative project delivery methods such as design-build or via public private partnerships. This trend has led to the notion that the traditional design-bid-build project delivery is no longer relevant on projects with values in excess of $100 million, i.e. mega-projects. This paper reports the findings of two case studies of mega-projects in Connecticut and Oklahoma that were successfully delivered using traditional methods. It finds that in order to manage the complexity associated with completing the design and construction of these major projects, project managers developed specific tools to cope with each project's political, public relations, and environmental context. The paper concludes the early recognition of the need to expand the project manager's role outside the routine cost-schedule-technical realm and early implementation of a project delivery strategy that included tools to deal with those context issues that ultimately will influence the final design and the construction schedule was the key to each project's success. Finally, this paper presents how these findings need to be incorporated into construction curriculum.

Keywords: Project management, case study, project delivery

Introduction

The traditional approach to project management (PM) has served the industry well during the expansion of U.S. transportation infrastructure. However, this infrastructure is now "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 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 (ASCE 2009). As a result, a shift from building new infrastructure to replace, expand, or renew existing infrastructure has occurred. The PM issues involved with infrastructure renewal are markedly different than the issues for new construction, furthering the need for a change in PM approaches to the nation's infrastructure. "Projects do not take place in a vacuum" (Leicester 2009). Not only are rapid renewal projects inherently more complicated, the situation has been exacerbated by years of under-funded 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. The people charged with managing these critical projects are typically civil engineers. The classic engineering curriculum is focused on the designer's skill set and pays lip service to the skill set necessary to produce an infrastructure project manager. This "technical-only" educational model has created a perception that engineers are merely "classic 'nerds' that have to be carefully controlled by 'managers' who have a solid understanding of the political process, financial issues, and formation of public policy and public opinion which engineers 'clearly' do not have" (Matteson 2001). In other words, engineers are not well prepared to manage large complex projects.

The 1990s exacerbated the issue by the demand to deliver public infrastructure projects faster and with more control over time and cost (Lopez et al. 2008; Sillars 2009). In the past two decades, the approach to project delivery has evolved to where alternative project delivery methods such as design-build (DB) and construction manager-at-risk (CMR) are now widely accepted and form important tools in the public agency's procurement toolbox (Lopez et al. 2008). However, many state agencies are unable to use these tools to expedite project delivery because they do not have the necessary legislative authority. Therefore, these agencies must adapt the traditional design-bid-build (DBB) project delivery method to the requirements of rapidly renewing a deteriorated infrastructure while continuing to provide reliable capacity for the traveling public in their jurisdictions. To do this, project managers are expanding the tools they do have for use on large complex DBB projects. This paper will detail the successful experiences documented in case studies for the I-40 Crosstown project in Oklahoma City, Oklahoma and the I-95/New Haven Crossing Corridor Improvement project in New Haven, Connecticut emphasizing the non-traditional tools the project managers developed for each of these traditionally delivered projects. It will also identify the PM skill set for complex projects to fill the hole in the existing civil engineering curriculum.

Background

The definition of successful PM is expanding to include broad, holistic, and long-lived measures of project performance (Jugdev and Muller, 2005). Marshall and Rousey (2009) posit a three-part definition of successful PM as follows:

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

As part of the redefinition of project success, roles and responsibilities of project managers are expanding beyond the traditional cost—time—quality triangle (Atkinson, 1999) to include management of relational, cultural, and stakeholder issues (Clelland and Ireland, 2002). In the midst of this evolution, the definition of PM has become blurred, and there is a lack of consensus on best practices. For instance, one book describes PM 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 utilizes the systems approach to management by having functional personnel assigned to a specific project" (Kerzner 2006). Other contemporary PM 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 others. Very few, if any, of these skills are currently resident in most civil engineering curricula.

Traditional Project Management

Traditional PM involves integrating the three dimensions of a project that must be satisfied to deliver the required scope of work (Marshall and Rousey 2009). These are technical, schedule, and cost. Figure 1 illustrates the concept that the scope of work is essentially defined by these three dimensions. The hallmark of traditional PM is its underlying assumption that the details of design will drive the project's cost and schedule (Atkinson, 1999) and thus, the project's technical/functional requirements are fixed. As a result, it is this PM dimension drives the other two. In other words, the design is only a function of the technical/functional requirements and the cost and schedule dimensions are purely a function of the design dimension. However, increasing governmental mandates for environmental, social, and other non-technical requirements have increasingly more influence on the final design details (Whitty and Maylor, 2009).

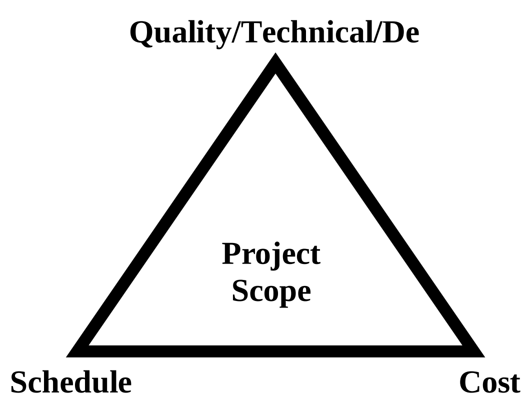

Figure 1: Traditional Project Management (after Marshall and Rousey 2009)

As a result, the project's context, i.e., the environmental, political, and social setting in which the project must be delivered is becoming the driving force behind the details of the final design. The impact of a project's context on the design has effectively added another dimension that project managers must satisfy to deliver complex projects. This creates a need to differentiate between the routine and the complex PM skill set and probably defines the difference between a complicated, but routine, project and a complex project. The PM curriculum at the nation's universities teaches the three dimensional approach to PM (Matteson 2001) dealing with context in the design dimension, failing to account for the fact that project context is a dimension that markedly constrains the design process and requires specific PM skills. Thus, the notion of complex project management as a field separate from traditional project management is proposed by the authors, and that a curriculum that furnishes entry-level engineers with the foundational knowledge needed to become successful complex project managers is needed.

Complex Project Management

A typical example of the complexity in transportation projects is Interstate Highway 405 in Portland, Oregon (ODOT 2009). This highway's 40+ year old concrete pavement carries 125,000 cars per day and has literally been ground down to the reinforcing steel by studded snow tires. Not only is this road in an urban area with very heavy commuter traffic, but it also needs 26 bridges and overpasses to be raised to meet current FHWA clearance requirements. Raising these structures will cause a ripple effect on the arterial and collector streets that connect with I-405 interchanges, raising their grades as well. In at least one case, the grade of the street will literally be raised to nearly the second floor of a building that fronts it. The situation is further complicated by the need to lower and/or relocate an unusually large number of utilities that crisscross the project limits. In fact, the engineering is less complex than the context in which the reconstruction must take place. Highly sophisticated PM procedures will be required to complete this complex project.

The problem with traditional PM cost and schedule control is particularly acute in large, complex projects as noted in the final report of NCHRP Project 20-69: *Guidance for Transportation Project Management* (Marshall and Rousey 2009). This study's results indicate that of projects over $5 million dollars in construction cost, less than 20% were on or under budget and only 35% were delivered on time. The study further identifies 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 phases of project development. The conclusion of the study is that most of these issues can be mitigated through the use of effective PM protocols and procedures, specifically early and consistent coordination between departments and agencies responsible for these project tasks from the beginning of the project. The study 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 new standards, training programs, and certification processes for a special class of project managers specifically trained to manage complex projects (Whitty and Maylor, 2009). Developing that curriculum will furnish the next generation of PMs the skill set necessary to succeed in future of complex project delivery.

Case Study Projects

To illustrate the ability to create the PM tools necessary to carry out complex mega-projects without resorting to alternative project delivery methods, two case studies are presented, information was collected through interviews and published data. The outcomes of the two case study analyses will then be used as a basis to identify a proposed skill set for complex PM that can serve as the basis for revising the current engineering curricula. Table 1 contains a synopsis of the salient facts of the two projects. Both are clearly mega-projects as defined by the Federal Highway Administration (2006), which classifies projects whose values exceed $100 million with that term.

Both projects are very complex in that they combine road improvements, bridges, and must be designed and built to coordinate with an existing railroad line. Both involved complicated right-of-way (ROW) acquisition. Both projects were subject to a great deal of scrutiny since they were delivered in states that rarely are challenged by projects of these magnitudes and as a result needed to assure the local taxpayers and business enterprises that the projects would not be packaged in a manner that would effectively eliminate local design consultants and construction contractors from being able to compete for the work. Both projects were major improvements to interstate highway routes through heavily urbanized areas and as such, required careful planning to ensure that disruption of traffic was kept to a minimum, and both projects were built through areas that were repeatedly crossed by a myriad of utility lines that required relocating to permit the construction of new structures and roadway. Finally, the state departments of transportation (DOTs) were not authorized to utilize alternative project delivery and as a result, needed to deliver these projects using traditional DBB. In a nutshell, both projects were clearly complex the following reasons:

1. The projects were much larger than projects typically delivered by both DOTs.
2. The projects required extensive coordination with third party stakeholders such as utility companies, railroads, and property owners.
3. The projects' alignment placed them in the public eye from concept to ribbon cutting and created an environment where the impact of political sensitivities overwhelmed fundamental technical/functional requirements and drove the final design, the project delivery schedule, and the sequence of design and construction work.
4. The DOT project managers found themselves needing tools to deal with requirements that were outside the realm of engineering and construction and with which they had neither prior education nor training.
5. The projects took place in jurisdictions that because of their relatively small populations had no prior need to investigate alternative project delivery methods like DB or CMR.

Table 1
Case Study Project Summary

Factor	I-40 Crosstown, Oklahoma	I-95/New Haven Crossing, Connecticut
Scope	4 ½ miles of new four-lane interstate including 6 new interchanges/bridges in an existing railway corridor in an urban area in Oklahoma City	Roadway improvements along 7.2 miles of I-95 and the new Pearl Harbor Memorial Bridge that is the nation's first extradosed bridge
Cost	$600 million	$416 million of a $1.9 billion program
Design-Construction Schedule	11 years	14 years
Project Delivery Method	DBB	DBB
Major Context Issues	• Size of project- issues with design and construction for local industry • Railroad relations • Project political sensitivity issues due to location in the CBD • Public relations related to Right-of-Way acquisition	• Project political sensitivity issues due to location in urban corridor • "No Bid" on bridge because of size and risk associated with design. • Two historic structures in the alignment • Scheduling issues with utilities, railroad, business entities, etc. • Massive amount of contaminated soil
Successful Accomplishments	• Non-adversarial relationships with the public and with the railroads • Project planning phase extremely in-depth - Solved potential problems early • Project Development Engineer assigned exclusively to this project • Single point of contact for public to voice concerns throughout planning and construction	• Contractor outreach plan to get input on bridge design and repackaging of solicitation based on local capabilities. • Value engineering workshops including contractors during planning • Project planning phase extremely in-depth – especially with utility relocations. • PM assigned to coordinate with utilities and the railroad.

I-40 Crosstown Project Case Study Results

The I-40 Crosstown project in Oklahoma City is a complex project. The planning and procurement phase started in March of 1995, and construction was underway in November of 2005 with the first of 23 work packages, the I-40 Canal Bridge. Figure 2 shows the alignment, work packaging, and timeline. Early in the planning phase the Oklahoma DOT (ODOT) found completing it as a single project would be an undertaking that local design and construction firms would not be able to handle. Also, due to constraints of federal funding, ODOT believed being able to receive such a large allocation would be unlikely. For these reasons, ODOT split the project into work packages so that local firms would be able to realistically compete for the projects. Because the project is being built in an existing railroad corridor, the relationships with the railroads were also extremely important. ODOT worked extensively with the Burlington Northern Santa Fe Railroad and the Union Pacific Railroad throughout the planning phase of the project to reach a design solution that was acceptable to all parties.

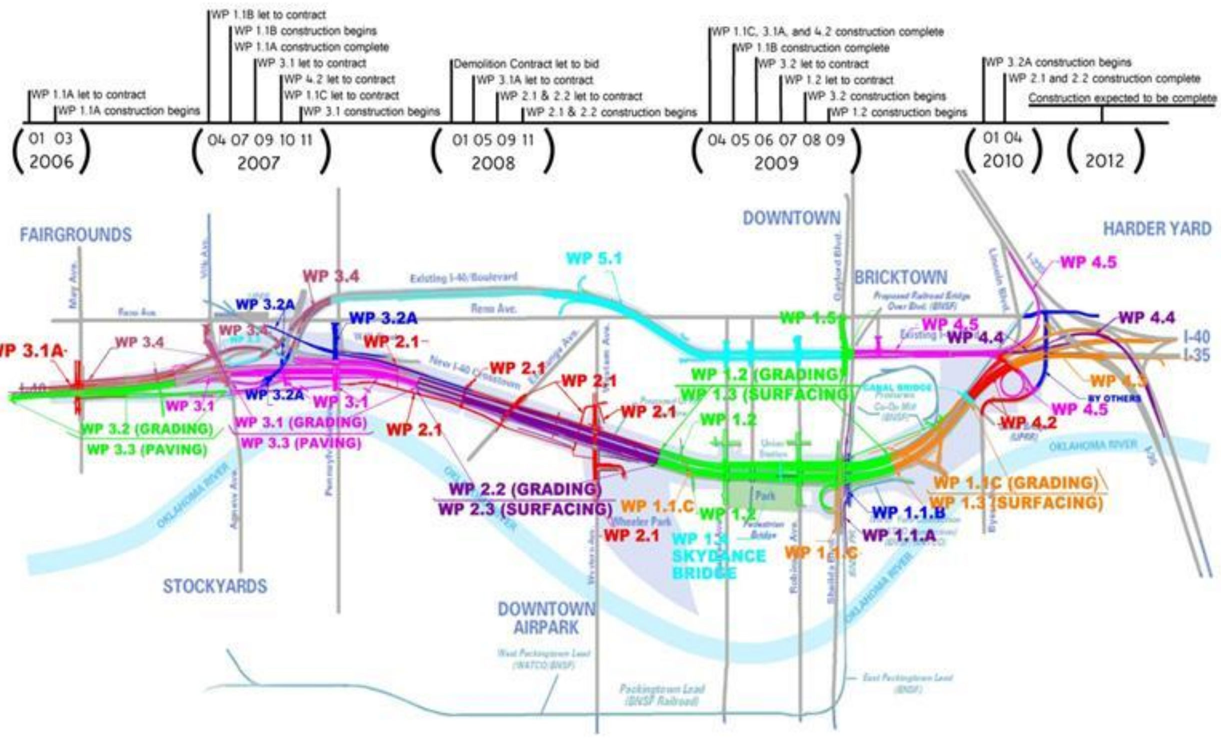

Figure 2: I-40 Crosstown Alignment and Timeline.

The major public relations issue was the impact on the neighborhood via relocation of residents and business. ODOT worked with the impacted groups and with their input selected a final alignment that while it had a greater impact on the relocation of minority and low-income residences, minimized the impact to minority and low-income businesses than the other alternatives. Another issue was the increase in possible noise and vibration. The project is located directly adjacent to the Riverside Neighborhood, and future traffic noise levels were estimated to exceed that of the Federal Highway Administration (FHWA) Noise Abatement Criteria. Noise barrier walls were added to mitigate the noise levels for the residential areas along the route. Due to public concern, ODOT performed structural surveys before and after construction is completed for several buildings and found no vibration issues. Additionally, including various state and city organizations in the public information effort was also very important. There was a concerted effort made to ensure that the residents and leaders of Oklahoma City were involved in the process to bring the most suitable solution to replacing the current dilapidated I-40 that runs through the heart of the city. The planning process from inception to completion took a total of ten years. The efforts put into the beginning of the project to include the public and other stakeholders reduced the number of issues that had to be resolved during design and construction. ODOT continues to keep the public informed as the construction progressed via a website dedicated to keeping the public up to date.

Table 1 lists the major project context issues that were encountered by ODOT in the course of the project. It also lists a number of measures that were taken to cope with the demands placed on the ODOT PM to successfully deliver this project. The interview with this individual revealed that the project's success can be ascribed to extensive in-depth planning. It also furnished the necessary information to identify the tools that the PM used to cope with project demands outside the traditional cost—time—quality triangle. These tools are as follows:

- Intensive detailed planning effort at early stages of project inception.
- Work package sizing that kept local firms competitive.
- Extensive public relations and information program that began as soon as the requirement to solicit and incorporate public input was realized.
- Early continuing negotiations with third party stakeholders to obtain the necessary technical information required for the agency to obtain the necessary construction permits from the railroad, utility companies and other public agencies like the Department of Environmental Quality.

- Extraordinary effort to identify those aspects of environmental, real estate, and contract law that represented potential barriers to progress and early solution-finding to satisfy these constraints.

I-95 New Haven Crossing Project Case Study Results

The I-95/New Haven Harbor Crossing project consists of roadway improvements along 7.2 miles of I-95, between New Haven and Branford. The Connecticut DOT (ConnDOT) included the new Pearl Harbor Memorial Bridge, the nation's first extradosed bridge. The program is complex because it features many scheduling, technical, and context-related challenges encompassing transit and highway work. The project size and location made scheduling the major issue the timing of project financing appropriations that dictated what could be constructed at any given period, the number of entities involved, the difficulty in scheduling activities around a busy and active artery, in a densely populated area all contributed to the scheduling challenges. A major complexity issue was the interdependence of projects. The delay in the completion of one project could impact the start time of other projects.

Figure 3: I-95 New Haven Crossing Project Alignment.

Several historic buildings, including the Yale Boathouse, the Fitch Foundry, the Long Wharf, and West Haven expansion efforts caused major delays and increased program costs. The extradosed main spans of the new Pearl Harbor Memorial Bridge were designed in both steel and concrete, allowing bidders to choose the least cost alternative. The bridge contract was the largest and most complex package. The new bridge project received no bids. The reason for lack of bids was that the bid package was too large and complex for the contracting community, especially local contractors and those with prior ConnDOT experience, and was deemed extremely risky by potential bidders. As a result, ConnDOT divided the project into multiple contracts which lead to increased time requirement for finishing the project. The repackaging of the bridge caused significant delays and cost increases. Utility coordination was another complex issue facing the project. The total cost of utility relocation is estimated at $85 million. All kinds of utility lines lie in a crowded corridor and major coordination with multiples agencies and corporations was needed to plan and execute relocations.

Table 1 also shows the challenges and achievements of ConnDOT on this project. The major difference between this case and the ODOT case is that the tools used by the ConnDOT PM were arrived at after the issues arose instead of before they took place. This put ConnDOT in a reactive mode for most of the project. It provides a vivid juxtaposition that supports the argument that complex PM is a different field than the routine three dimensional process currently in the nation's education system. A comparison of the two cases revealed that while both were successfully completed, the fact that ODOT chose to quantify the external impacts and allow them to shape the design solution rather than find that the final design solution for the major feature of work was too large and too risky to attract competent bidders shows the critical need for engineers to be well-versed in fields beyond engineering design to successful meets this nation's need to replace its aging and structurally deficient infrastructure.

Conclusions and Recommendations

Four conclusions are drawn from the above analysis of the two case studies. Four recommendations that flow from the conclusions are also offered.

Conclusions on Complex Project Management Skills

First, the need for complex PMs to understand and be able to properly *implement public information planning* is critical to the success of complex DBB projects. Since the design of DBB projects must be complete before award of the construction contract, it is critical to identify those project context aspects that must be addressed by the design itself before the scope of design is fixed. The success of both the I-40 and I-95 projects was attributed to their PMs recognizing the public and political sensitivities inherent to each project and addressing those early in the planning process. Additionally both PMs adopted a "what do you need" attitude rather than the typical engineer's "this is what is needed" approach to public relations. In essence, each project was managed in a manner that allowed the input from the non-DOT stakeholders to drive the final design solution; as opposed to reacting to negative public reactions that cause design changes when the political pressure becomes too great to withstand.

Next, the *ability to successfully negotiate* with public and private entities was clearly a tool that facilitated the successful completion of both projects. Again, both PMs recognized the potential risk associated with external stakeholders such as the railroad and utility companies that would be impacted by the projects. Again, both assumed the same approach as was used to deal with the public. They opened negotiations early in the planning process and allowed the technical details of the final design be negotiated at a point before design effort would have been wasted to make changes necessary to obtain the necessary permits.

The environmental and right-of-way acquisition issues that each project had to accommodate were formidable and required the PM to have *a working knowledge of environmental and contract law.* In both cases, the development of mitigation plans went beyond the mere technical environmental engineering design and required the involvement of outside interests to achieve a reasonable solution. The "no bid" situation that occurred on the I-95 project clearly demonstrated the consequences of not having considered the context in which the new bridge would be built. The PM's solution was to develop flexible design criteria and repackage the project in a manner that allowed local contractors to bid without exceeding their bonding capacity or risk profile. The I-40 project started with this as a constraint and developed the project in design and construction packages that were of an acceptable size and composition to make local engineering and construction firms competitive.

Finally, the most significant success factor in each case was clearly the early in-depth planning process that was overseen by the same project manager. This demonstrates a need for the complex PM to *understand the principles of regional and city planning* and be able to apply them to the complex project. Additionally, the two cases ably illustrate the need for the complex project to be managed by a life cycle project manager that stays with the project from concept to ribbon cutting. The traditional system is typically a "relay race" with a new PM at each stage of project development. The holistic approach used in both cases requires a project manager that understands the critical elements of each phase in the complex project's life cycle.

Recommendations for a Complex Project Management Curriculum

Taking the above conclusions as areas in which engineers require a formal educational foundation leads to the following four recommendations. These should be taken as suggestions to enhance the civil curriculum in a manner that will at least produce entry-level civil engineers into public service with an introductory knowledge of the skill sets found to be required by the case study project managers.

1. To understand the importance and application of public information planning, the engineering student will require coursework in communications and public policy.

2. The skill set required to be able to successfully conduct negotiations is extensive. However, engineering students need to understand negotiating theory and the rules associated with conducting ethical negotiations.
3. A survey course on the principles of environmental and contract law as applied to public infrastructure projects would sensitize entry-level engineers to the absolutes that are inherent to these two fields and a course built around infrastructure case studies would assist the student in understanding how the underlying legal principles are applied on complex projects.
4. Proper prior planning is essential to successful complex PM and as such, coursework that comes from the regional and city planning discipline would be of great value and furnish a working vocabulary of the planning process and how it might be applied in life cycle project management.

To summarize, managing complex DBB projects forces the engineer out of the traditional three dimensions shown in Figure 1 and requires the project manager to utilize "soft" skills and allow the external stakeholder, rather than the technical requirements, shape the final design solution and its attendant scope of work. Adding coursework in the areas of communications, public policy, negotiating, environmental and contract law, and city planning will produce an entry-level engineer that is better equipped to tackle the enormous challenge represented by a complex DBB infrastructure project.

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