Developing Flexibility through Alternative Project Delivery Methods for the U.S. Army Corps of Engineers Project Management Business Process

by

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Submitted to the System Design and Management Program in Partial Fulfillment of the Requirements for the Degree of

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Abstract

Inflexibility, failure to adapt technology, and overly regulatory processes frustrate construction industry productivity and reduce the likelihood that large infrastructure projects will be delivered on-schedule and on-budget. Divergence from entrenched project delivery methods can provide flexibility to project managers and offers advantages for improving quality, collaboration, costs, and timeliness. The objective of this research is to provide the U.S. Army Corps of Engineers (USACE) recommendations for their Project Management Business Process (PMBP).

This study reviews the current state of project management in USACE, conducts a structured systems architecture analysis of the PMBP, evaluates USACE project statistics, assesses alternative project delivery methods through a literature review, and provides case studies to consider the implementation impediments of alternative methods for public and private projects. USACE serves as the nation’s largest public engineering agency with responsibilities in military construction, civil works, water navigation, environmental restoration, and disaster response. This research concludes with recommendations for selecting alternative project delivery methods best-fit to meet the distinct needs of each USACE business program. Explicitly, the application of Integrated Project Delivery is best suited for highly specialized, technical projects for military construction and interagency support, but also presents contractual challenges not-yet adapted for USACE. Public Private Partnerships show promise for possible future implementation in civil works projects, but require further refinement through the USACE Pilot Program. Lastly, Construction Management at Risk is the most mature alternative method for USACE, and can provide Project Managers with additional options in fast-tracking and early contractor involvement. Essentially, the flexibility of PMBP project delivery should match the vast diversity of USACE’s missions.

Thesis Supervisor: Richard de Neufville, Ph.D.
Title: Professor, Engineering Systems; MIT Institute for Data, Systems, and Society

Disclaimer: The views expressed in this thesis are those of the author and do not reflect the official policy or position of the U.S. Army, Department of Defense, or the U.S. Government.
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<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AAR</td>
<td>After Action Review</td>
</tr>
<tr>
<td>ACEC</td>
<td>American Council of Engineering Companies</td>
</tr>
<tr>
<td>AE</td>
<td>Architecture and Engineering</td>
</tr>
<tr>
<td>AEC</td>
<td>Architecture, Engineering, and Construction</td>
</tr>
<tr>
<td>AFARS</td>
<td>Army Federal Acquisition Regulation Supplement</td>
</tr>
<tr>
<td>AGC</td>
<td>Associated General Contractors of America</td>
</tr>
<tr>
<td>AGC</td>
<td>Army Geospatial Center</td>
</tr>
<tr>
<td>AIA</td>
<td>American Institute of Architects</td>
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<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
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<tr>
<td>BIM</td>
<td>Building Information Modeling</td>
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<tr>
<td>BRAC</td>
<td>Base Realignment and Closure</td>
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<tr>
<td>CAD</td>
<td>Computer-Aided Design</td>
</tr>
<tr>
<td>CDF</td>
<td>Cumulative Distribution Function</td>
</tr>
<tr>
<td>CIO</td>
<td>Chief Information Officer</td>
</tr>
<tr>
<td>CMAR</td>
<td>Construction Management at Risk</td>
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<tr>
<td>COAA</td>
<td>Construction Owners Association of America</td>
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<tr>
<td>CSF</td>
<td>Critical Success Factors</td>
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<tr>
<td>DB</td>
<td>Design Build</td>
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<tr>
<td>DBB</td>
<td>Design Bid Build</td>
</tr>
<tr>
<td>DBOT</td>
<td>Design-Build-Operate-Transfer</td>
</tr>
<tr>
<td>DFARS</td>
<td>Defense Federal Acquisition Regulation Supplement</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>EBD</td>
<td>Evidence-Based Design</td>
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<tr>
<td>ECI</td>
<td>Early Contractor Involvement</td>
</tr>
<tr>
<td>EFARS</td>
<td>Engineering Federal Acquisition Regulation Supplement</td>
</tr>
<tr>
<td>ER</td>
<td>Engineer Regulation</td>
</tr>
<tr>
<td>ERDC</td>
<td>Engineering Research and Development Center</td>
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<tr>
<td>ESF</td>
<td>Emergency Support Function</td>
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<tr>
<td>FAR</td>
<td>Federal Acquisition Regulation</td>
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<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
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<tr>
<td>GMP</td>
<td>Guaranteed Maximum Price</td>
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<tr>
<td>GSA</td>
<td>General Services Administration</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>HVAC</td>
<td>Heating, Ventilation, and Air Conditioning</td>
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<tr>
<td>ICL</td>
<td>Incentive Compensation Layer</td>
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<tr>
<td>IDBB</td>
<td>Integrated Design-Bid-Build</td>
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<tr>
<td>IDIQ</td>
<td>Indefinite Delivery, Indefinite Quantity</td>
</tr>
<tr>
<td>IIS</td>
<td>Interagency/International Support</td>
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<tr>
<td>INCOSE</td>
<td>International Council on Systems Engineering</td>
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<tr>
<td>IPD</td>
<td>Integrated Project Delivery</td>
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<tr>
<td>LEED</td>
<td>Leadership in Energy and Environmental Design</td>
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<tr>
<td>MBSE</td>
<td>Model-Based Systems Engineering</td>
</tr>
<tr>
<td>M/E/P/FP</td>
<td>Mechanical/Electrical/Plumbing/Fire Protection</td>
</tr>
<tr>
<td>MHS</td>
<td>Military Health System</td>
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<tr>
<td>MILCON</td>
<td>Military Construction</td>
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<tr>
<td>NAD</td>
<td>North Atlantic Division</td>
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<tr>
<td>NAE</td>
<td>New England District</td>
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<tr>
<td>NASFA</td>
<td>National Association of State Facilities Administrators</td>
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<td>NAVFAC</td>
<td>Naval Facilities Command</td>
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<tr>
<td>OPM</td>
<td>Object-Process Methodology</td>
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<tr>
<td>OMB</td>
<td>Office of Management and Budget</td>
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<tr>
<td>P3</td>
<td>Public Private Partnership</td>
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<td>PDT</td>
<td>Project Delivery Team</td>
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<tr>
<td>PEB</td>
<td>Pre-Engineered Building</td>
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<td>PM</td>
<td>Project Manager</td>
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<td>PMBP</td>
<td>Project Management Business Process</td>
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<td>PMI</td>
<td>Project Management Institute</td>
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<td>PMP</td>
<td>Project Management Plan</td>
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<tr>
<td>PQR</td>
<td>Project Quarterback Rating</td>
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<tr>
<td>RFI</td>
<td>Request for Information</td>
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<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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Chapter 1. Introduction

1.1. Status of U.S. Infrastructure

Underinvestment in America’s aging infrastructure system leads to domestic concern, economic inefficiencies, and missed opportunities in the national and global marketplaces. To understand the extent of the infrastructure deficit, this study considers an internal evaluation of U.S. infrastructure by the American Society of Civil Engineers (ASCE), and an external comparison to other modernized nations by the World Economic Forum. Additionally, key indicators of the construction industries’ downturn include losses of productivity, schedule delays, and cost growth, and this thesis will address the prevalence of these negative construction industry factors.

Infrastructure Report Card

Every four years, the ASCE provides an infrastructure report card to grade the nation’s essential services across 16 categories, including parks, schools, transportation, and energy, among others. The 2017 report score for the nation’s infrastructure was a ‘D+’ and continues along the trend of sub-par grades over the past two decades as shown in Figure 1.1. In each of the categories, engineering specialists grade the country’s infrastructure with the following criteria: capacity to meet current and future demands, conditions of current infrastructure as-is, funding ratio of what is dedicated versus what is needed, future funding concerns, operations and maintenance of infrastructure, public safety risks, infrastructure recovery and resiliency in case of disaster, and the level of innovation in the infrastructure sector (American Society of Civil Engineers, 2017). The ASCE report points to greater investment, infrastructure leadership, and future planning to stem the current trend and improve the nation’s infrastructure trajectory. While some regions of the country score better than others and variations exist across the multiple categories, the ACSE infrastructure report card macro-approach is still a valuable statement as to the current state of the nation’s infrastructure.
Figure 1.1. ASCE Report Card History (American Society of Civil Engineers, 2017)

Global Competitiveness Report
The World Economic Forum provides the annual Global Competitiveness Report which evaluates each individual country and global regions on their financial growth opportunities. A component of their multi-layered competitiveness rating includes an assessment of overall
infrastructure. The 2016-2017 report evaluates the U.S. as the 3rd highest Global Competitiveness Index for all categories, but the quality of overall infrastructure ranks 12th globally (World Economic Forum, 2017). This ranking is also noted in the 2018 Presidential Budget Request calling for increased action and interest in both public and private infrastructure investment (Budget of the U.S. Government, 2017). While a 12th place global ranking in infrastructure isn’t shocking, the 2012-2013 World Economic Forum gave American infrastructure a 25th place ranking as shown in Figure 1.2. As Business Insider remarked in January of 2013, the report “exposes that U.S. infrastructure compares unfavorably to that of most advanced countries and even some developing nations” (Kawa, 2013).

![Figure 1.2. The 2012-2013 World Economic Forum assessed U.S. infrastructure as 25th globally (improved to 12th in the 2016-2017 report) (Kawa, 2013)](image)

Global Infrastructure Ranking
The World Economic Forum’s global ratings indicate that American infrastructure is not consistently in the top-ten, despite the prominent economic status of the U.S. As national infrastructure ages and is replaced, the construction industry’s role in delivering projects on-time, on-budget, and at the agreed-to quality can account for a portion of this infrastructure deficit. Despite dramatic changes to the technological and information landscapes that are shaping many American businesses, the U.S. construction industry is not experiencing the cost-
savings and revenue-generation benefits on par with other industries. A 2015 study by McKinsey & Company shows that while the construction industry sees flat or declining progress, productivity in the manufacturing sector is nearly doubling over the past 20 years (Changali et al., 2015).

**Overview of productivity improvement over time**

Productivity (value added per worker), real, $2005

<table>
<thead>
<tr>
<th>Year</th>
<th>Manufacturing</th>
<th>Construction</th>
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<tr>
<td>1994</td>
<td>65</td>
<td>60</td>
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<tr>
<td>1996</td>
<td>70</td>
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<td>2010</td>
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<td>100</td>
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<tr>
<td>2012</td>
<td>110</td>
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</table>

![Figure 1.3. Overview of construction industry productivity (Changali et al., 2015)](image)

**Mega-Project Cost and Schedule Study**

In the same McKinsey & Company study, a sample of 60 large-capital, mega-projects of $1 billion or more are evaluated for cost and schedule growth. As shown in Figure 1.4., the sample of projects has an average schedule slippage of 20 months and budget overage of 80% (Changali et al., 2015). The research lists several systemic factors contributing to a lack of productivity and the cost/schedule growth: poor organization and decision making, communication inconsistencies, performance management, unknown contractual obligations, desynchronized planning, short term operations, risk management, and talent management.
Where other sectors of industry have benefitted from automation of assembly or production, digitalization of information, and data-driven analytics and decisions, the construction industry remains plagued with deficient productivity. Coupled with productivity loss, the industry generally fails to deliver projects at-schedule and on-budget in a consistent manner. But even with these trends, the ASCE report card indicates that a significant work surge and capital investment is required soon to halt the decline of the nation’s infrastructure and boost the nation’s economic potential. Federal infrastructure is often relied-upon for several years beyond its intended design lifespan, and the U.S. Federal Highway Administration acknowledges that one quarter of American bridges are over 50 years old (surpassing the design-life of the average bridge) (National Association of Corrosion Engineers – International, 2017). As much of the nation’s infrastructure quickly reaches its designed limits, the government agencies responsible for ensuring that public infrastructure need to get more value out of tax dollars, and should consider the use of innovative methods.
1.2. Role of the U.S. Army Corps of Engineers (USACE)

The U.S. Army Corps of Engineers is a direct reporting agency to the U.S. Army Headquarters, within the Department of Defense (DoD). They serve as the U.S. Army’s construction managers and are the chief proponents for military construction on both U.S. Army and U.S. Air Force installations. Additionally, through historical and ongoing authorizations, USACE is charged with maintaining and developing water navigation and civil works projects across the U.S., with responsibilities ranging from harbor expansion, inland waterway dredging, flood protection, and environmental restoration, to name a few. Furthermore, under specified conditions, other federal agencies, states, and even local municipalities may call on USACE to execute construction management on their behalf. USACE engages in several other responsibilities including, but not limited to, federal land operations, military and civil works research, disaster response, and geospatial support, but the management and execution of large infrastructure projects remains a chief pillar of the organization.

USACE Personnel
USACE employs over 35,000 personnel performing an incredibly diverse array of roles and responsibilities in the government and engineering realms. The USACE workforce includes approximately 1,000 uniformed Army Soldiers (Enlisted, Non-Commissioned Officers, and Officers), but the vast majority of employees are DoD civilians. Additionally, through government appropriations for projects, studies, and research, USACE contractually employs thousands of architects and engineers, and hundreds of thousands of construction equipment-operators, tradesmen, and general contractors. USACE is headquartered in Washington, D.C. and is comprised of 9 Divisions with 41 Districts spread geographically across the nation, and with additional offices at overseas duty locations. Aside from the operational activities within the Divisions and Districts, USACE HQ manages centers for financial, logistical, and support operations; several research and development facilities; a direct-reporting active-duty Army Battalion specializing in electrical production and distribution; and a support and administration staff to manage the business and programs (USACE 101, 2016).

USACE Appropriations
Examing government appropriations toward military construction and civil works provides a sense of the magnitude of USACE programs and spending. When the House Appropriations Committee released its Fiscal Year 2016 Military Construction Legislation, they allocated a total
of $7.7 billion for military construction projects across all service branches (Committee on Appropriations, U.S. House of Representatives, 2016). For civil works projects, the President’s 2018 Budget Request proposes $5 billion for Corps of Engineers projects (Budget of the U.S. Government, 2017). Additional funding for projects comes from other government agencies, international projects, or military installation maintenance funds. USACE reports $20.3 billion in total program spending across their military support and civil works lines of effort for Fiscal Year 2016 (USACE 101, 2016).

USACE Construction Market-Share
USACE’s 2016 program spending follows the current downward trend from the height of military construction during the Army’s recent BRAC program (Base Realignment and Closure). September 2011 marked the deadline for the completion of the Army’s BRAC ’05 Plan, and during the comprehensive base construction program period, USACE executed 274 military construction projects, constituting the largest military construction program since WWII (Ward, 2011). At the peak of BRAC spending in 2008, USACE managed a total military construction and civil works project portfolio of over $49 billion (USACE 101, 2016). A 2010 presentation by the American Council for Construction Education notes the Department of Commerce’s estimation for total construction industry spending at nearly $1 trillion annually, including public, private, and residential projects (Smith, 2010). At that time, nearly $50 billion was spent in the military and civil works programs of USACE, and thus, the Corps of Engineers accounted for nearly 5% of annual construction in the U.S. While total construction industry spending is slightly increasing, USACE spending is dramatically decreasing, and thus, the percentage of total annual construction is closer to 1.75% in 2016 (Merryman, 2017).

USACE Missions
The USACE project portfolio includes military support, civil works, interagency and international support, and various other lines of business. While only accounting for a small percentage of annual construction in the U.S., the secondary influences of USACE-led projects and ongoing operations provide a significant contribution to the U.S. economy as shown in Figure 1.5. Aside from managing construction operations on the several hundred military bases within the U.S. and abroad, USACE programs support public recreation, transportation and trade, environmental restoration projects, and protective levees and dams. Inland waterways, managed through the USACE civil works program, provide the primary method for the shipment of agricultural grains and oilseeds from the nation’s heartland (Water, Marine Transportation,
and Related Infrastructure Investment, 2017). Additionally, USACE-owned dams and hydropower facilities account for roughly 40% of the U.S. hydropower consumption or 3% of the nation’s power (Thorndike, 2016). USACE flood risk management prevents over $8 of potential catastrophic damages for every $1 spent on flood control infrastructure (Water, Marine Transportation, and Related Infrastructure Investment, 2017). And lastly, with over 400 lake and river projects, USACE is one of the nation’s leading providers of outdoor recreation (Civil Works Recreation, 2017). The Corps of Engineers maintains a multifaceted engineering role to support the U.S. Army, DoD, and the nation’s needs, and as the federal government’s construction experts, USACE plays a prominent role in delivering large, public infrastructure projects.

**USACE Civil Works Programs**

3% of Nation’s Electricity: $800 M + in sales

Stewardship of 11.7 M Acres Public Lands

~11,750 miles of Levees

Recreation Areas 370 M visitors / yr

Generate $10 B + 350 K jobs

Emergency Responses

12,000 miles of Commercial Inland Waterways

50% cost of Rail: 10% cost of Trucks

926 Harbors

400 miles of Shoreline Protection

72,000 Regulatory Permits

~ $250B in Replacement Value

**Figure 1.5. Info-graphic of the USACE Civil Works program with key areas of focus**

(Thorndike, 2016)
1.3. Research Purpose, Goals, Methods, and Resources

**Purpose:** The purpose of this research is to provide an understanding of the current state of project delivery within USACE, analyze USACE project delivery statistics to determine cost and schedule growth trends within the agency, explore alternative project delivery methods used for public infrastructure, and provide recommendations on future implementation to improve USACE project delivery flexibility. On-trend with the industry, USACE is confronted with mounting public infrastructure challenges and may need to explore and implement alternative methods to meet the nation’s needs.

**Goals:** This thesis research provides an analysis of the status-quo, an overview of alternative project delivery methods in the industry, a presentation and analysis of case studies, and a recommendation for incorporating greater flexibility in project delivery method selection. The thesis:

- Provides initial context for the research by covering the current state of the construction industry and national infrastructure, the role of USACE, key stakeholders in USACE project delivery, the USACE project process, an explanation of USACE lines of business, and a brief history of the Corps of Engineers.
- Covers a systems architecture decomposition of the Project Management Business Process using Object-Process Methodology as the modeling language.
- Analyzes objective evaluation metrics of cost and schedule growth for comparison to private or public industry standards and norms.
- Discusses alternative project delivery options and provides a literature review exploring studies of public infrastructure development using alternative methods, with an emphasis on benefits, disadvantages, and barriers to implementation for USACE.
- Explores case studies of the alternative project delivery methods, discussing lessons learned, implementation strategies, constraints, and challenges.
- Provides a framework for USACE project delivery method selection incorporating alternative methods when applicable.

**Research Method:** Approaching USACE project delivery as a complex system, the ‘V-Model’ of Systems Engineering provides a framework for engineering a solution that meets requirements and stakeholder needs, considers tradespace concepts, and defines system components. The
International Council on Systems Engineering (INCOSE) states that "systems engineering is a profession, a process, and a perspective" and defines systems engineering as "an interdisciplinary approach and means to enable the realization of successful systems" (International Council on Systems Engineering, 2017). A similar systems engineering approach is used in recommending alternative project delivery options for use within USACE, following the systems 'V-Model' (Figure 1.6.) as a framework.

The "V-Model" of Systems Engineering

![V-Model Diagram]

Figure 1.6. ‘V-Model’ of Systems Engineering (de Weck, 2016)

As the INCOSE handbook notes, "the core of the Vee depicts the evolving baseline from user requirements agreement to identification of a system concept to definition of systems components that will comprise the final product" (International Council on Systems Engineering, 2017). While not strictly adhering to the model, or completing the systems' approach through Commissioning Operations or Lifecycle Management, this thesis research project incorporates the following components in-line with this process of problem solving:
- A USACE stakeholder analysis and project delivery requirements definition vetted through the USACE New England District, Project Management Office.
- A structured system architecture analysis of the existing USACE PMBP process given the Corps of Engineers project management training program.
- An exploration of alternative project delivery methods using targeted research of engineering journals, academic papers, and policy forum reports.
- An assessment of USACE project delivery practices and project cost and schedule evaluation metrics using multiple Districts' historical project records.
- An analysis of private and public-sector case studies and resources to determine best-practices in implementing alternative project delivery methods.
- A framework for integrating alternative project delivery methods into USACE.

Resources: To accomplish this research project required the support of the USACE New England District and additional support from around the Corps of Engineers. The New England District provided valuable insight into the operations and processes of project delivery within the Corps, multiple project site visits, and historical project data for the past 20 years. The USACE HQ Alternative Financing Program Office provided reports and presentations pertaining to ongoing efforts to implement alternative project delivery methods within USACE.

Additionally, MIT professors and senior lecturers provided instructional material and research that aided in the completion of this project. The System Design and Management graduate program provided a basis in Systems Architecture, Systems Engineering, and Systems Project Management. Professor Richard de Neufville’s courses in Risk and Decision Analysis as well as Real Options for Systems Design were instrumental in evaluating historical project data and project flexibility. Finally, Senior Lecturer Christopher Gordon’s course on Innovative Project Delivery provided the impetus for the research project, and considerable insight into the ‘best-practices’ of alternative delivery methods utilized in the private sector.

With a process grounded in the principles of systems engineering, and with the goal of establishing a framework for implementing alternative project delivery within the Corps of Engineers, the USACE New England District offered the support needed to execute the thesis research. Considering the growing challenges to public infrastructure, alternative project delivery strategies, which are not frequently implemented by USACE, could provide increased project delivery flexibility, and improve efficiency in terms of cost, schedule, and quality.
Chapter 2. USACE Project Management

2.1. Key Project Stakeholders

For USACE, effective project management is crucial to the organization's mission of delivering "vital public and military engineering services" (Mission & Vision – Headquarters U.S. Army Corps of Engineers, 2017). As the ‘V-Model’ of Systems Engineering implies, an analysis of key participants, or stakeholders, follows an evaluation of the current state of the system. An understanding of the differing needs of key stakeholders assists the project manager in reducing complexity and garnering support from project influencers.

Given the brief description of the role of the U.S. Army Corps of Engineers, its diverse set of missions, geographical distribution, and assorted clients, the entirety of the project delivery structure could most certainly be classified as a complex system. As stated in Systems Architecture, “a complex system has many elements or entities that are highly interrelated, interconnected, and interwoven” (Crawley et al., 2016). The complexity of USACE programs is apparent through the diverse set of interests and requirements generated by the key stakeholders, the volumes of regulatory and legal guidance, the rigorous methodology for attaining project funding, and the echelons of command and control from project concept to completion.

The relationships and interactions between stakeholders enables USACE to affect multiple missions but also contributes to complexity and generates an essential desire for synchronization amongst interested parties to execute projects. Systems Architecture differentiates the primary entities affected by a system as beneficiaries (“those who benefit from your actions”) and stakeholders (“those who have a stake in your product or enterprise”) (Crawley et al., 2016). For USACE projects, military construction beneficiaries include: military units, service members, and service member families; and civil works beneficiaries can include: local residents, recreational area users, direct business affiliates, or indirect/peripheral private businesses.

To establish an understanding of the complex stakeholder environment that exists for USACE project delivery, the primary needs are mapped in the stakeholder diagram shown in Figure 2.1. and key stakeholders are described below. The exchange of policy, money, project services,
knowledge, and needs drive a system of interactions between the key stakeholders. The stakeholder analysis map depicts those relationships and interactions, and displays the apparent complexity of the project delivery environment surrounding USACE. Understanding the value flow within the stakeholder analysis provides context to the interactions, and assists in prioritization and determining stakeholder motivations.

Figure 2.1. USACE project delivery stakeholder analysis map

(1) **U.S. Army Corps of Engineers – Headquarters**: Located in Washington, D.C., the USACE HQ consists of several directorates and offices providing oversight on projects and operations across the organization's business lines. It works with lawmakers within the capital to ensure regulations and standards of practice are consistent with current legislation and legal proceedings. Additionally, the USACE HQ provides leadership and guidance to subordinate organizations, coordinates work effort across
Divisions, and publishes updated Engineer Regulation and Bulletins to inform the force.

(2) **U.S. Army Corps of Engineers – Divisions and Districts:** As depicted in Figure 2.2., USACE is comprised of geographically separate Division HQs with assigned District offices around the U.S. and abroad. Generally speaking, individual Districts are responsible for the military installations and civil works projects found within their region. District leaders and USACE Engineers work with Army and Air Force installation managers to plan, design, fund, and execute military construction projects.

![Figure 2.2. Info-graphic of USACE locations (U.S. Army Corps of Engineers – Headquarters, 2017)](image-url)
District leaders also work with regional government officials including national and state congressional senators and representatives, state governors, city and county officials, local mayors, and regional industry leadership. Infrastructure needs are generated in every echelon from local to federal, and if a project study or construction contract is validated and appropriated through official channels, the USACE Districts work directly in the project region with interested stakeholders. Division HQs provide leadership and guidance for the Districts within their footprint. Division HQs level work requirements and pool resources to accomplish major regional infrastructure projects.

(3) Department of Defense – U.S. Army: USACE is a Direct Reporting Agency of the U.S. Army, and thus is subject to certain regulations, requirements, and guidance that governs the nation's Army. USACE Headquarters is led by the Chief of Engineers, an Army Lieutenant General, while the Divisions are commanded by Major Generals or Brigadier Generals, and the Districts are commanded by Colonels or Lieutenant Colonels. Major construction on all Army military installations is managed by USACE to include new projects, large-scale maintenance, or base clean-up and closures. Across the several hundred Army installations within the U.S. and abroad, Directorates of Public Works (or similar organizations) often complete operations, maintenance, and small projects, but major new construction and large infrastructure maintenance is executed through the Corps of Engineers.

(4) Department of Defense – U.S. Air Force: Similarly, major construction on all Air Force military installations is managed by USACE to include new projects, large-scale maintenance, or base clean-up and closures. The U.S. Air Force also has several hundred installations within the U.S. and abroad, and all major new construction or large infrastructure maintenance is executed through USACE.

(5) U.S. Congress – House of Representatives and Senate: Congress determines infrastructure funding for the DoD including military installation construction projects and closures. It also determines the authorizations and appropriations for federal Civil Works projects and studies through the Water Resources Development Act issued every few years. Defense committees provide oversight on USACE operations and project management and provide recommended changes to regulations governing USACE project execution and reporting. For example, the U.S. Senate Committee on Armed Services convened in July of 2017 to construct the National Defense Authorization Act of Fiscal Year 2018. In discussing recent military construction, the hearing presented additional oversight reforms as shown in Figure 2.3.
Subtitle D--Project Management and Oversight Reforms

Project management oversight reforms

The committee is concerned with the number of construction projects that are experiencing significant schedule delays and cost increases. The recent notification that the Hospital at Fort Bliss, Texas would cost an additional 250 million because of "omissions" and "design errors" is just one example of poor management of these projects with little to no accountability for those responsible. With other significant

Notification requirement for certain cost overruns and schedule delays (sec. 2831)

The committee recommends a provision that would amend section 2833 of title 10, United States Code, to require the Secretary of Defense to notify the congressional defense committees of any military construction or military family housing project that has a cost overrun or a schedule delay of 25 percent or more.

Figure 2.3. Excerpt from U.S. Senate hearing on military construction oversight reform (Senate Report 155-125, 2017)

(6) U.S. Executive Branch – Office of Management and Budget (OMB): The President’s budget request is generated through the OMB and highlights changes to fiscal policy and the funding of the federal government and its agencies. For example, the Fiscal Year 2018 Budget of the United States Government proposes an increase in DoD spending of $51 billion dollars from 2017 to 2018 ($594bn to $643bn) but a reduction in spending for USACE of $1 billion dollars ($6bn to $5bn) (Budget of the U.S. Government, 2017).

(7) USACE Districts’ jurisdictions – States, Counties, and Cities: District boundaries are generally drawn to encompass specific regions of the U.S. or abroad with groupings of common infrastructure needs (often directly based on watersheds, lakes, shorelines, or rivers). Within the Districts, federal and state officials have vested interests in the infrastructure development in their regions including the projects themselves, employment opportunities, military installation development and closures, and environmental impacts.

(8) Other Government Agencies – Environmental Protection Agency, U.S. Customs and Border Protection, etc.: Other federal agencies work with USACE for construction management services when required. If a federal project meets certain regulations, and other project management avenues are exhausted, USACE can
complete large infrastructure projects with funding that is appropriated for federal construction. Several government agencies do not possess sufficient construction expertise and resources, and thus outsource their project management to the Corps of Engineers.

(9) **International Governments and Militaries:** On a reimbursable basis, international governments can work with USACE for design and construction management services when required. Tribal governments and allied nations may request USACE expertise to execute civil works or military construction projects. The Foreign Assistance Act, the Water Resources and Development Act, and the Arms Export Control Act all govern the types of projects and processes that USACE must adhere to in supporting allied nations (USACE 101, 2016).

(10) **Construction Industry Private Sector – Architectural and Engineering Firms, General Contractors, Tradesmen, etc.:** While USACE performs a portion of the research, planning, and execution for projects, the final plans, studies, or construction delivery are often provided through negotiated contracts with the private sector. Private Architecture and Engineering firms (AE firms) account for over 65% of the technical planning and design of projects, and nearly 100% of the building execution is performed by private construction contractors (USACE 101, 2016).

(11) **Engineering Societies, Academia, and Consultants – American Society of Civil Engineers, Harvard Kennedy School - Ash Center, Private Consulting Firms, etc.:** With a recent political push to further U.S. investment in infrastructure using private funding, there is increasing interest in engineering consultants and academia to assist in the evolution of private investment in federal projects. Alternative project delivery methods are increasing in regularity but still face significant constraints and challenges in the current regulatory environment, and thus academia, engineering societies, and consultants are actively engaged in research to improve the industry. Within the past year, several collaborative efforts and publications have addressed alternative public project financing, public-private partnerships, and tapping private investment to modernize America’s infrastructure (Goldsmith and Jamieson, 2017; Williams, C., 2017; Temple and Jamieson, 2017).
2.2. USACE Project Delivery Governing Policy

The essential business of USACE is to deliver infrastructure projects for Military Construction, Civil Works, and Interagency/International Support. While USACE serves other missions for the DoD, U.S. Army, and federal government, project delivery remains its stalwart responsibility. The unified process for project execution at USACE is captured in the Project Management Business Process (PMBP), and the regulatory framework for USACE activities is codified in a series of Engineering Regulations (ERs) established by USACE. In accordance with all DoD branches, the underlying acquisition and budgeting guidance is provided through the Federal Acquisition Regulation (Federal Acquisition Regulation, 2017).

Project Management Business Process
The USACE PMBP Brochure states: “the Project Management Business Process is the conceptual guidance by which the U.S. Army Corps of Engineers executes projects in a consistent manner” (PMBP Brochure, 2009). The PMBP establishes a framework for project delivery from concept to completion, with 4 phases consisting of 22 processes, and it is applicable for all USACE work that is deemed a ‘project.’ As the Project Management Institute (PMI) defines, and USACE publications reiterate, a project is “a temporary endeavor undertaken to create a unique product, service, or result.” Last revised in May 2009, the PMBP Manual, Version 1.0 extensively covers the process phases and steps, and associated references for executing project delivery (PMBP Manual, 2009).

Engineer Regulations
The evolution of modern project management policy for USACE is directed through the publication and revision of Engineer Regulations. In 1992, ER 5-7-1: Project Management defined the modern “concepts and rules of project management” to govern USACE project delivery (Engineer Regulation 5-1-11, 2007). First released in 1998, ER 5-1-11: USACE Business Process carried-over those previous policies to ‘program’ management, and applied the PMBP with newly created automated information systems to organize project data. ER 5-1-11 was revised in 2001 to include the “USACE Business Process Imperatives” and directed the organization away from the trend that “all work is a project.” Revised again in 2007, ER 5-1-11 remains the governing regulation defining USACE business doctrine, directing non-project work and corporate data, driving the PMBP, and establishing roles and responsibilities.
Federal Acquisition Regulation (FAR)

The FAR provides the regulatory guidelines for federal agencies to purchase or lease services and goods, and is the basis for acquisition procedures for USACE. “The Federal Acquisition Regulation System is established for the codification and publication of uniform policies and procedures for acquisition by all executive agencies” (Federal Acquisition Regulation, 2017). The Engineer Federal Acquisition Regulation Supplement (EFARS) implements and adds to the Defense FAR Supplement (DFARS) and the Army FAR Supplement (AFARS). Last issued in March of 2005, but with periodic updates, the FAR consists of 53 separate parts addressing every aspect of the federal acquisitions process. Those 53 parts are collected into the following 8 chapters: FAR – General, Competition and Acquisition Planning, Contracting Methods and Contract Types, Socioeconomic Programs, General Contracting Requirements, Special Categories of Contracting, Contract Management, and Clauses and Forms. Within each USACE Division and District, contracting office representatives assist Project Managers in executing contracts within the scope of FAR criteria.

Key Federal Legislation

USACE must consistently be mindful of relevant changes to construction policy, infrastructure financing, and government contracting on the federal, state, and local levels to ensure compliance. Government policy is constantly changing, and updated legislation must be considered in the planning, financing, and delivery of USACE projects. Three pieces of federal legislation with significant impacts on USACE project delivery are:

- The 1972 Brooks Act implements qualifications-based selection, which ensures that USACE awards all AE firm contracts based on demonstrated competence and best-quality, and not the lowest bid (American Council of Engineering Companies, 2017).
- The 1984 Competition in Contracting Act requires that all federal procurement be conducted in a full and open manner with rare exception, and that bid submissions be open to any qualified company (U.S. General Services Administration, 2012).
- The 1996 Clinger-Cohen Act encompasses two separate pieces of legislation, the Information Technology Management Reform Act, and the Federal Acquisition Reform Act. The Federal Acquisition Reform Act provides that unless the traditional design-bid-build method is used, the only other authorized acquisition procedure is the two-phase contract for design and construction, also known as ‘design-build’ (10 U.S. Code 2305a, 1996).
2.3. Task Organization and Structure

With federal legislation guiding government acquisition and contracting, the Corps provides a project management process to deliver projects within their statutory parameters. The stakeholder analysis offers insight into the external influences regulating and prompting USACE project delivery, however, the internal structure and organization of USACE is also a complex hierarchy of command relationships and support systems. Appendix A provides an explanation and organizational structure for each level of command from the Department of Defense to the USACE District.

Department of Defense (DoD)
The DoD is led by the Secretary of Defense, and is composed of the Joint Chiefs of Staff, Departments of the Army, Navy, and Air Force, and the several Defense Agencies and Field Activities. USACE is a federal agency under the DoD and the Department of the Army.

Department of the Army
USACE is designated a Direct Reporting Unit by the Secretary of the Army. The Chief of Engineers is the Army’s senior engineer expert, and serves as a member of the Army Staff, advising the Chief of Staff of the U.S. Army.

U.S. Army Corps of Engineers (USACE)
USACE HQ works with federal lawmakers, adjacent government agencies, and military leaders to develop national infrastructure priorities and deliver programs along their lines of business.

USACE Divisions
The 9 USACE Divisions are spread geographically across the U.S. and the Division Headquarters’ contain regional business directorates and program directorates to address the Divisions’ lines of business and major initiatives.

USACE Districts
The 41 USACE Districts are distributed across the U.S. and abroad and support the lines of effort in their designated territories. The Districts operate independently, but they also collaborate throughout USACE for resource availability, and coordinate lessons-learned and design specifications through designated centers of expertise and centers of standardization.
2.4. USACE Lines of Effort

USACE maintains a diverse set of missions to meet the needs of the nation and the military. The project delivery process and the design of the organization's structure are geared toward delivering these Lines of Effort. Despite drastic differences in the types of programs that USACE pursues, there are commonalities in the project delivery methods that govern planning and execution in each domain. Recognizing the variety of USACE missions provides context to the application of the project management process and is important to understanding the need for flexible project delivery strategies.

- **Military Missions**: Military construction projects represent the earliest requirements of the U.S. Army Corps of Engineers. The first mission given to the Corps was the planning and development of earthworks in the defense of Bunker Hill during the Revolutionary War. In 1802, the nation's first engineering school was founded as the United States Military Academy at West Point, training young Army officers with an education in engineering. From the onset, USACE was responsible for the planning, design, and execution of military construction projects within the U.S. and abroad. As of 2016, the Military Support business program executed $13.5 billion in construction projects (USACE 101, 2016). As the Army's engineers, USACE continues to serve as construction managers for all Army and Air Force installation projects and overseas contingency base construction efforts. Additional missions include environmental clean-up and base closures, real-estate management, and Global War on Terror contingency operations support and reconstruction efforts.

- **Civil Works**: In 1824, USACE was entrusted by the federal government with the surveying and management of federal waterways from legislation including the General Survey Act and the Rivers and Harbors Acts. To this day, USACE provides construction support for river navigation, flood risk management, recreational area operations, emergency response mitigation, and environmental protection. The Civil Works program delivered $6.8 billion in infrastructure projects in 2016, and remains a critical component of maintaining the nation's vital inland waterway transit (USACE 101, 2016).

- **International and Interagency Services**: USACE has a longstanding history of providing technical engineering support to non-DoD federal organizations, as well as state and local governments. Mostly conducted on a reimbursable basis, USACE
performs engineering studies or construction management for other government agencies that require the expertise or assets to execute projects. Additionally, USACE may support international organizations or foreign governments with engineering services, environmental protection training, natural resources management planning, and other technical services (U.S. Army Corps of Engineers – Interagency & International Support, 2017).

- **Contingency Operations:** The Federal Emergency Management Agency (FEMA) is responsible for the preparation, protection, and response of the nation’s most critical hazards. If activated for a federal incident, FEMA calls upon Emergency Support Function (ESF) Coordinators to lead the efforts within their domain. USACE is responsible for executing ESF #3, the protection, repair, and restoration of public works and infrastructure. Additionally, USACE is a supporting organization for the execution of ESF #9, life-saving assistance and search and rescue operations (National Response Framework, 2017). Furthermore, USACE sends disaster response personnel all over the world to provide technical expertise, emergency power generation, critical infrastructure assessments, and critical commodity support (U.S. Army Corps of Engineers – Emergency Operations, 2017).

- **Geospatial Support:** The Army Geospatial Center (AGC) is headquartered in Alexandria, Virginia and supports the other USACE Lines of Effort with geospatial products, research, and technology. The AGC’s main missions include terrain research and analysis, imagery and sensor collection and analysis, hydrological and navigation data capture and management, and support to civil works and other agency projects (Army Geospatial Center, 2017).

- **Research and Development:** The U.S. Army Engineer Research and Development Center (ERDC) supports the Army warfighter, USACE civil works, military installations, and other government agencies with scientific research and testing. ERDC has roughly 2,100 employees positioned across 7 laboratories with an annual research budget of over $1 billion (U.S. Army Engineer Research and Development Center, 2017). Through work agreements, ERDC may execute research for state and local governments as well as private industry, but the primary research areas include: warfighter support, installations, environment, water resources, and information technology.
The range of USACE Mission Areas reflects the constantly changing role of the Army Engineer in the nation's history, and understanding that history provides perspective on the nation's need for a federal construction management organization with ties to the military and national infrastructure. USACE plays an integral part of America's Army and the development of federal infrastructure projects, and the discussed Lines of Effort provide insight into current operations and ongoing priorities. As the need for federal infrastructure investment has grown from the nation's humble origins, so has the role of U.S. Army Engineers. Throughout the nation's history, there have been periods of intense infrastructure investment, and many see the current state of U.S. infrastructure as requiring a similar stimulus effort.

Analysis

In keeping with the framework of the Systems Engineering ‘V-Model,’ this chapter analyzes the existing process for delivering projects in USACE, the Project Management Business Process (PMBP). The modern PMBP has been in use for over twenty years and reflects the changing conditions of the construction industry, technological advances, and the Information Age.

3.1. PMBP Principles

The PMBP is a USACE internally-created system that provides the framework steps, inputs, and outputs to navigate the project delivery process given the robust bureaucratic environment in which the Corps of Engineers operates. The 2009 PMBP Brochure lists implementation benefits including: a focus on customer inclusiveness, efficiency through operating regionally and virtually, and consistency in program and project execution. The PMBP Principles allow for future process evolution through the “use of best practices and seeking continual improvement” (PMBP Brochure, 2009). And thus, the PMBP Process should not be a rigid framework, but an evolving model seeking constant realignment. As the Chief of Engineers directs, the eight principles guiding all USACE project work include:

1. Plan for success and keep commitments.
2. Measure quality with the goals and expectations of the customer in mind.
3. Build effective communications into all activities and processes.
4. Use best practices and seek continual improvement.
5. Use corporate automated information systems consistently and accurately.
6. One project, one team, one Project Manager (PM).
7. Manage all projects with a Project Management Plan (PMP).
8. The Project Delivery Team (PDT) is responsible for project success.
3.2. PMBP Systems Architecture

The Corps of Engineers project delivery process is an architecture for executing projects from initial-need to close-out. In thinking about intricate systems, two key elements are critical to reducing complexity: decomposition and architecture representation tools (Crawley et al., 2016). Decomposition is simply the breaking down of a system into smaller, usable components – the ‘divide and conquer’ method. Architecture representation tools allow for the visualization and organization of complex systems with immense amounts of information into a single, usable model. Appendix B provides additional detail and figures discussing the decomposition of the PMBP and the application of architecture representation tools.

Decomposition

The PMBP shown in Figure 3.1. represents the level 1 functional decomposition of the Project Life-Cycle. It is a four-phase process for executing projects: Project Initiation, Project Planning, Project Execution & Control, and Project Close-out (PMBP Brochure, 2009). Decomposing the process down to understand the inner-workings-of and interactions-between each phase, the PMBP provides 22 discrete, ordered activities to be executed. This level of decomposition provides a reasonably understandable model for how USACE approaches the project delivery process. However, delving into each activity further decomposes into flowcharts of tasks and decisions for execution by multiple USACE parties. Reducing the complexity of the entire project process, the level 1 decomposition of the PMBP provides a sufficient explanation for project delivery for the purposes of this research.

Architecture Representation Tools

As stated in Systems Architecture, “a complex system contains an enormous amount of information – far more than any single human can readily comprehend” (Crawley et al., 2016). A single activity can spawn additional requirements or decisions, and the usability of an un-layered model quickly deteriorates. To reduce complexity, an integrated model is required to incorporate form, function, and their relationships into a single architecture. Appendix B offers an initial application of Object-Process Methodology (OPM) for modeling the PMBP. While restructuring the PMBP is outside of the scope of this thesis, the application of Model-Based Systems Engineering could promote a more flexible PMBP model. OPM meets this criterion and “allows systems analysts and engineers to keep system models in a single, unified form that facilitates model evolution, maintenance, and team communications” (de Weck et al., 2011).
Figure 3.1. USACE Project Management Business Process (PMBP Manual, 2009)
3.3. Delivery Team

The development of the team that delivers the project, is a far greater indicator of USACE project success than the elements of the PMBP process. Project delivery at the USACE District can be considered a complex engineering system, as each individual project is in-and-of-itsel a system with distinct components and complex interactions with a "high degree of technical and social complexity" (de Weck et al., 2011). To ensure that individual projects are executed within the legal framework of USACE business lines, regional construction requirements, and congressional budgets requires a diverse team of managerial, engineering, and administrative professionals.

Project Customer
As shown in the PMBP, Figure 3.1., the process is initiated with an identified customer need and work acceptance approval by USACE District leadership. ER 5-1-11 directs that "the Project Manager (PM) assures customer involvement throughout the process and ensures mutual understanding of the customer's role in project success. The PM’s relationship with the customer is pivotal to achieving project success" (Engineer Regulation 5-1-11, 2007). Additionally, “the PM and the PDT work with the customer early in the project scoping process to determine what the customer needs, and to refine those requirements in light of safety, fiscal, schedule, legal, and other constraints.”

Project Manager (PM)
Once work is accepted, a PM is assigned from the Programs and Project Management Division within the USACE District. From ER 5-1-11, the PM is responsible for ensuring the customer’s objectives are "clearly articulated and that the customer understands the essential professional standards, laws, and codes, as well as public trust issues, that must be incorporated into the project" (Engineer Regulation 5-1-11, 2007). Once assigned, the PM is responsible for the assembly of the PDT.

Project Delivery Team (PDT)
Selection of the PDT members depends on the skillsets required of the project. From ER 5-1-11, “the PM provides leadership and facilitation to the PDT; a multi-disciplined project team with responsibility for assuring that the project stays focused, first and foremost, on the public interest, and on the customer’s needs and expectations and that all work is integrated and done
in accordance with a Project Management Plan (PMP) and approved business and quality management processes” (Engineer Regulation 5-1-11, 2007). The PDT is resourced within the District by members from the various technical and advisory offices, including: contracting, real-estate, design branch, general engineering, construction, and technical engineering specialists as required (water resources, electrical, civil, structural, geology, and environmental engineering). Lastly, per ER 5-1-11, “individual PDT members are responsible and accountable for the quality of their own work, for keeping the commitments for completion of their portion of the project as documented in the PMP, and for fiscal stewardship.”

Additional USACE Resources
USACE Districts may request additional support or resources from adjacent Districts or elsewhere across the Corps. The Division and USACE HQ distribute resources and projects to ensure consistent work levels across regions. Additionally, Centers of Expertise and Centers of Standardization throughout USACE provide subject-matter support and pre-engineered building plans and designs upon request. For example, the Savanna District office completes a significant amount of military construction projects and with that expertise, they are the designated as the Center of Standardization for several types of military facilities: Company Operations Facilities, Brigade Operations Complexes, Corps HQ buildings, etc. (Westcott, 2017).

Architecture – Engineering Firms
When project design efforts clearly range beyond the scope of in-house USACE technicians or pre-fabrication designs, the PM and District Leadership must establish the Project Delivery Acquisition Strategy for AE Firm and Contractor services. In some cases, the District can rely on pre-established Indefinite Delivery/Indefinite Quantity (IDIQ) contracts to expedite design plans. IDIQ contracts are pre-negotiated bundles of work between a USACE Division or District and a single AE Firm or a collective of AE Firms. When feasible, USACE may work with the available AE Firms within the IDIQ contract to complete designs against the remaining balance of the contract. The design price is still negotiated upon, and the overall time savings to the USACE Districts are significant. If the requested project design is innovative or resource-intensive, the District may need to execute a formal bidding process in accordance with the Brooks Act. Finally, if the Project Delivery Acquisition Strategy selected is Design-Build, the AE contract responsibility falls upon the Design-Build contractor. Additional variants for AE Firm selection
may exist, but generally, USACE relies on in-house services, IDIQ contracts, Design-Build contractors, or AE Firm new-contract bidding for the execution of design work.

**General Contractors**
As mentioned, the work capacity of the District and the magnitude of the project both influence the Project Delivery Acquisition Strategy selected during the Project Planning Phase. The District leadership will choose the project delivery method, selecting, with rare exception, between Design-Bid-Build and Design-Build. These project delivery methods will be explained in detail in Chapter 5, but both incorporate the added management and construction services of a General Contractor. While USACE Districts possess a Construction Management Division (see Figure A.6. for the New England District structure), these engineers largely serve as the owner’s representative, executing and coordinating quality control of the project.

**Project Hand-Over Team (Certifications, Operations, and Maintenance)**
As the PMBP describes, USACE project close-out requires an after-action review and compiled lessons learned. The as-built blueprints and final punch-list items must be delivered to the customer upon project completion. On many projects, facilities inspectors must approve electrical, water, or gas connections and final structural certifications must be provided. Military construction is often transferred to the installation management organization, and interagency projects are handed-over entirely. While some civil works projects are transferred to other authorities, many projects remain under the jurisdiction of USACE. In those situations, the District’s operations and maintenance divisions will take-on responsibility of the facility upon project completion. Examples for the USACE New England District include: Corps dams with associated lake and river basins, the Cape Cod Canal, and multiple storm-surge hurricane barriers (New England District, 2016).
Chapter 4. USACE Project Management Business Process – In-Practice Analysis

4.1. Project Process as Executed

While Chapter 1 provides context to the current state of the industry and the role of USACE, Chapter 2 expands on USACE project delivery, stakeholders, regulations, and the organization’s structure. And where Chapter 3 outlines the Project Management Business Process and the development of the project delivery team ‘as-designed,’ this section will address some of the practical realities that the Corps of Engineers faces in executing complex infrastructure projects. The observations in this section are provided through Corps of Engineers employee discussions:

- **USACE as a matrix organization:** When the PDTs assemble assets from across the organization, a multiple-manager conflict can ensue over personnel priorities.

- **USACE construction management through resident offices:** Often, projects are centrally planned at a District office and guided by that central office staff and project manager through the point of general contractor selection. But, during construction execution, the construction management division provides quality control from satellite, resident offices, and the management oversight (and control), of the project shifts.

- **USACE coordination with Centers of Expertise and Centers of Standardization:** Across the Corps, these Districts must be involved in the planning and review of projects that fall within their purview of specialization. While beneficial, this can also lead to overlapping responsibilities and cross-country project influence.

- **Implications of the rigidness of the PMBP:** As a guide for project delivery, the PMBP provides the step-by-step instructions to meet USACE requirements. However, every unique project calls for improvisation and deviation from the plan, which challenges adherence to a standardized PMBP template.

- **Developing the Project Acquisition Strategy:** This determination drives several future decisions and aspects of the PMBP. But essentially, the course of action selected is nearly always Design-Bid-Build or Design-Build.

- **Risk avoidance and mitigation within the District:** Separate offices may have conflicting interests in terms of risk avoidance within a District. While financing and contractual risks are the foremost concern by the Contracting Office, these may conflict with any non-standard project methods proposed by the PM Division.
4.2. Project Stakeholder Analysis

The key stakeholder analysis in Figure 2.1. provides insight into the external influencing factors surrounding USACE project delivery, but each stand-alone project team must examine their unique situation to determine which entities are most influential, and which are most interested. Additionally, within each stakeholder organization, echelons of leadership represent internal chains of command, and provide avenues for the escalation of approvals or conflicts.

Figure 4.1. Stakeholder Map for USACE New England District Project (Kraus, 2017)

Figure 4.1. represents an ongoing project at the USACE New England District and the stakeholders invested in the project's outcome. The different organizations have assessed levels of interest in the project, and in many cases, the end-user customers are highly interested in project outcomes, but their influence over the bureaucratic process is minimal. Congress usually has ultimate funding authority over civil works, interagency, and military support projects, but customers can influence the process through informal channels. That funding authorization works its way through the military branches, installation priorities, and eventually benefits the end users. For Military Construction (MILCON), USACE is typically working for military installations that have substantial influence over project factors and schedules.
4.3. Key Metrics for USACE Project Delivery

Analyzing project data for cost and schedule growth can provide indicators for delivery success and establish an understanding of USACE project delivery as-executed. Historic project data from USACE Districts provides key insights into general cost and schedule efficiency and an understanding of the quantity and magnitude of the executed projects. The project data from the USACE New England District covers a 20-year period from 1997 to 2016, and includes all completed projects over $2 million in final contract cost. The total data set for the USACE New England District (designator – ‘NAE’) includes 159 projects in the Programs of Civil Works, Military Support, Interagency/International Support, and Environmental Support. In total, these projects represent $1.25 billion in design and construction contracts. Figure 4.2. displays the project data sample by program-type, and Figure 4.3. displays the projects by funding-bracket.

<table>
<thead>
<tr>
<th>Project By Type</th>
<th># Projects</th>
</tr>
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<tbody>
<tr>
<td>Civil Works</td>
<td>67</td>
</tr>
<tr>
<td>Military Support</td>
<td>42</td>
</tr>
<tr>
<td>IS (Interagency &amp; International Supp)</td>
<td>28</td>
</tr>
<tr>
<td>Environmental</td>
<td>22</td>
</tr>
<tr>
<td>Total Projects - 159</td>
<td>159</td>
</tr>
</tbody>
</table>

![USACE NAE Projects by Program (1997-2016, >$2MIL)](image)

Figure 4.2. USACE New England District Project Data By-Type (1997-2016)

<table>
<thead>
<tr>
<th>Projects By Cost</th>
<th># Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2ML - $5ML</td>
<td>91</td>
</tr>
<tr>
<td>$5ML - $10ML</td>
<td>39</td>
</tr>
<tr>
<td>$10ML - $50ML</td>
<td>28</td>
</tr>
<tr>
<td>&gt;$50ML</td>
<td>1</td>
</tr>
<tr>
<td>Total Projects</td>
<td>159</td>
</tr>
</tbody>
</table>

![USACE NAE Projects by Cost](image)

Figure 4.3. USACE New England District Project Data by Funding-Bracket (1997-2016)
Project cost growth data as a percentage of cost increase from initial contract to final contract is shown in Figure 4.4. With an average project cost growth of 20.7%, the data is significantly skewed at the upper bounds due to some projects with extensive cost growth. Note, that cost growth for this research includes all funding increases beyond the initial contract, even those due to modifications chosen by the customer or unforeseen delays beyond the control of USACE. A Cumulative Distribution Function (CDF) shows the probability of attaining projects with given percentages of cost growth. The range of project cost growth spans from -21.6% to +226.7%. Approximately 20% of the projects finish under-budget, with roughly 80% experiencing some cost growth. Additionally, about 23% of the sample (37 projects) have cost over-runs greater than 25%, and as indicated by the Senate Armed Forces Committee on military construction, projects with cost growth over 25% could come under additional oversite requirements (see Figure 2.3.).

<table>
<thead>
<tr>
<th>NAE Project Cost Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Variance</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Max</td>
</tr>
<tr>
<td>Min</td>
</tr>
<tr>
<td>5% chance of Cost Growth below</td>
</tr>
<tr>
<td>5% chance of Cost Growth higher</td>
</tr>
</tbody>
</table>

![CDF - USACE NAE Project Cost Growth](figure)

**Figure 4.4. USACE New England District Project Data – Cost Growth (1997-2016)**

Project schedule growth data as a percentage of time increase from initial contract scheduled completion to the final completion is shown in Figure 4.5. With an average project schedule growth of 53%, the data is again skewed by multiple projects with significant schedule over-runs. Similarly, the study does not differentiate between unplanned schedule over-runs, and agreed-to schedule increases. 99 of the 159 projects experience less than 25% schedule growth, which includes 62 projects that are reported as on-schedule. However, 5% of the sample experiences schedule over-runs of 200% or greater.
Lastly, the project data is viewed by program-type to determine if certain business lines perform better in terms of cost and schedule growth reduction. As seen in Figure 4.6., the cost growth by-program shows that environmental projects and civil works projects generally perform better, and on average have cost over-runs under 25%. The schedule-growth by-program is generally inconclusive, but civil works projects tend to have the least average schedule-growth. As Chapter 1 discusses, schedule and cost growth are a construction industry-wide concern, and the USACE New England data indicates that Corps of Engineers projects experience similar challenges.
CDF - USACE NAE Project Cost Growth - By Program

Probability

Percentage of Cost Growth (%)

-25% 0% 25% 50% 75% 100% 125% 150% 175% 200% 225%

NAE Civil Works Projects
Civil Works Mean
NAE Military Support Projects
Military Support Mean
NAE IIS Projects
IIS Mean
NAE Environmental Projects
Environmental Mean

CDF - USACE NAE Project Schedule Growth - By Program

Probability

Percentage of Schedule Growth (%)

-50% 0% 50% 100% 150% 200% 250% 300% 350% 400% 450% 500% 550% 600% 650% 700% 750% 800% 850% 900% 950%

NAE Civil Works Projects
Civil Works Mean
NAE Military Support Projects
Military Support Mean
NAE IIS Projects
IIS Mean
NAE Environmental Projects
Environmental Mean

Figure 4.6. Project Data – Cost & Schedule Growth by Program Type (1997-2016)
Chapter 5. Analysis of Alternative Project Delivery Methods

5.1. Project Delivery Methods and Principles

The American Institute of Architects and the Associated General Contractors of America jointly published the 2011 Primer on Project Delivery, providing guidelines for understanding alternative project delivery methods. As the publication states, “project ‘delivery’ refers to the method of assigning responsibility to an organization or individual for providing design and construction services” (Primer on Project Delivery, 2011). Project owners, some with insufficient funding or minimal subject-matter knowledge, look to alternative project delivery methods to close their resource gaps and meet their growing infrastructure requirements. The various project delivery methods provide owners with flexibility in addressing teamwork concerns, project costs, schedule, or project complexity, and can enhance the final construction product under the right circumstances.

Each project delivery method offers an array of advantages and disadvantages, and selection of the appropriate method relies on the needs and expertise of the owner. Some reasons for seeking alternative project delivery include: the transferring of project risk and rewards, the potential of expediting the project through fast-tracking, enhanced teamwork structures, established avenues for conflict resolution, flexibility to respond to site changes with reduced impacts, greater collaboration in the project design, and the establishment of incentives through cooperation.

While numerous project delivery methods exist, this thesis discusses the prevalent methods used by USACE (Design-Bid-Build and Design-Build), and three emerging alternative project delivery methods (Construction Management at Risk, Public Private Partnerships, and Integrated Project Delivery). While not a comprehensive guide to executing these project delivery methods, this thesis focuses on the unique characteristics of the methods and the benefits and drawbacks of utilization, from the point of view of the owner. As adapted from MIT Senior Lecturer Christopher Gordon’s research and engineering course in Innovative Project Delivery, the figures represent the project delivery organizational structures and the relationships therein (Gordon, 1991).
5.1.1. Design-Bid-Build

Often described as the 'traditional' method of project delivery, Design-Bid-Build (DBB) relies upon a linear approach to project execution. The owner contracts with the architect and engineers to develop the design and complete the project plans. Once finished, the completed plans are bid-on by various general contractors, allowing for a competitive bidding process. The project award process is generally based on the Best-Value or Lowest-Price and is often contracted using a Lump-Sum (Primer on Project Delivery, 2011).

Description
The primary requirements of the owner are in supplying general direction for design and construction, delivering available land, producing project financing, and arbitrating in the case of conflicts between the architects/engineers and contractors (Jones and Gibson, 2014). The architect and engineering firm is responsible for meeting the design requirements of the owner and producing a constructible set of final project plans. The general contractor is responsible for delivering the project according to plan and meeting the established schedule and budget, pending any change orders. The organizational structure is shown in Figure 5.1.

Advantages and Disadvantages
Advantages of the DBB method include: the competitive bidding process; established methods, roles, and legal/regulatory precedents; completed design and estimated final cost at contractor bidding; and maintaining the owner-architect fiduciary relationship (Gordon, 1991). Disadvantages of the DBB method often include: expensive and lengthy change order processes, conflicts between designers and contractors, siloed design effort without general
contractor buy-in, and slow project execution (Bender, 2003). Despite a few glaring disadvantages, DBB remains the most common project delivery method for infrastructure construction. Many public agencies and levels of government require the competitive bidding process of the DBB structure, and therefore, it remains the “delivery system of choice for public entities” in the U.S. (Jones and Gibson, 2014).

**Design-Bid-Build within USACE**

Design-Bid-Build is also the most common practice for USACE project delivery, and effectively represents the default option as the USACE project team enters the acquisition planning phase. As shown in Figure 5.2, the steady growth of Design-Build projects now rivals DBB for industry-wide project method market share, but DBB remains the prevalent project delivery method (National Society of Professional Engineers, 2016).

![Project Delivery Method Market Share for Non-Residential Construction](image)

**Figure 5.2.** The Design-Build Institute of America study of non-residential project delivery method market share (National Society of Professional Engineers, 2016)
5.1.2. Design-Build

The defining characteristic of Design-Build (DB) project delivery is that the owner executes both design and construction through a single entity. This method allows the owner to amalgamate all project contracts and responsibility to that single entity, the Design-Build contractor (Primer on Project Delivery, 2011). This contractor can be an architect or general contractor, and will employ subcontractors, architects, and engineers as required to fulfill the project requirements.

The construction industry saw declining productivity throughout the 1990's and into the 2000's, and public agencies sought a new method to reduce cost growth and speed-up project delivery (Stevens, 2014). After a trial period of pilot projects from the mid-1980's to the mid-1990's, the Clinger-Cohen Act of 1996 approved DB for use by the DoD for MILCON projects (Rosner et al., 2009). Once enacted into the U.S. Code, government agencies established regulations to administer DB projects, and its use became more prevalent. At that point, USACE provided its Commanders with Engineer Regulation 1180-1-9 (1999) which provides execution guidance for the use of DB contracting. A 2009 study of 835 Air Force MILCON projects (Figure 5.3.) also reinforced the project delivery method trend of DB encroachment on the traditional DBB method.

![Figure 5.3. Prevalence of Design-Build in Air Force MILCON Projects (Rosner et al., 2009)]
Description
The DB method provides the owner with a single entity for both design and construction, but success of this method depends on that owner's ability to initially communicate the design requirements and understand the construction systems enough to evaluate what is being provided (Bender, 2003). Often, the DB contract requires an extensive description of scope, and a level of pre-design or conceptual design, to allow potential bidders to fulfill the project proposal and estimate a fixed-price and schedule (Jones and Gibson, 2014). Aside from a clear initial requirements document and conceptual design, the owner is responsible for providing land and financing for the project. The Design-Build contractor is responsible for all design, construction, subcontractors, and team interactions or arbitrations. Given the single contract, the DB entity is accountable for errors or omissions from design to construction. However, considering the entire operation is less-siloed than the DBB method, a DB contractor can generally execute a project more quickly through fast-tracking. A cohesive project team can fast-track a project by starting initial construction work (land clearing, material ordering, or foundation work for example) once that segment of the design is completed, but prior to a 100% final design.

![Figure 5.4. Design-Build Structure](image)

Advantages and Disadvantages
Advantages of DB include: the fast-tracking of projects through 'just-in-time' construction plans, a sole entity responsible to the owner for all design and construction, cooperation between designers and builders with no arbitration requirement, a single bidding and proposal evaluation process, and known total costs and schedule if a fixed-price contract (Jones and Gibson, 2014; Gordon, 1991). Disadvantages of DB include: the requirement for owner in-house design and construction knowledge, loss of design control and architect-engineer fiduciary relationship, and over-reliance on a single DB contractor for the success of the project.
Design-Build Study of Federal Highway Projects
Not surprisingly, the rapid rise of Design-Build throughout the private and public sectors piqued the interests of researchers and government agencies that want to ensure the actual manifestation of these proposed DB benefits. In 2006, the Federal Highway Administration published a study of 140 DB projects representing $5.5 billion in construction from 1990 to 2002. The results concluded that the selection of DB had statistically insignificant effects on the overall project quality, and likewise, the impacts to total project cost were inconclusive in terms of the project method selected. However, the impacts of Design-Build on project timeliness showed benefits, with managers citing reduced project durations of 14%, on average, compared to other delivery methods. Additionally, a "significantly lower cost and number of claims" for DB projects was observed, contributing to fewer conflicts (Design-Build Effectiveness Study, 2006).

In summary, the DB method reduced the schedule and change-orders generated, but failed to impact the overall cost or construction quality for this sample of federal highway projects.

Design-Build Study of Air Force MILCON
The afore-mentioned study in 2009 evaluated the Air Force MILCON program from 1990 through 2000 to determine key comparisons between the DB method (278 projects) and DBB (557 projects). They found that DBB actually excelled over DB for minimizing total project duration, although admittedly, the study was constrained by database insufficiencies in comparing Design-Build start times and identifying fast-tracking (Rosner et al., 2009).

Nevertheless, the study indicated that the DB method outperformed DBB in terms of cost growth and quantity of modifications per million dollars of project. Additionally, the study evaluated all DB projects over two-year segments and determined consistent improvement over-time across each major performance metric (cost growth, total project time, and modifications per million dollars). Thus, for this sample of Air Force MILCON, DB outperformed DBB in project cost and change-orders, but underperformed in schedule-growth. Furthermore, the DB process incrementally improved in all categories as the project delivery method matured from 1990 to 2000.

MILCON Cost Premiums and USACE Challenges in Design-Build
A report on military construction premiums noted a House Armed Services Committee study that was conducted in 2011 which found roughly 25-40% unit cost premiums in the MILCON sector compared to equivalent commercial sector expenses (Blomberg et al., 2014). Seeking validation of key causes contributing to these military construction premiums, Blomberg et al.
evaluated two nearly identical DB projects building seven-bay aircraft hangars. One DB project was conducted through Air Force MILCON with USACE as the construction agent. The other project was developed by the base engineer unit using the U.S. General Services Administration to procure a pre-engineered building (PEB). The two identical project requirements executed with Design-Build contracts were managed quite differently, resulting in two entirely dissimilar structures (one PEB and one concrete masonry unit) which both met the initial design. Alarmingly, the PEB structure cost 27% less and took less than half the time to construct, so the researchers conducted expert interviews and quantitative analysis to determine the differences. They identified five cost-premium themes that can plague a military construction project, including those executed through Design-Build contracts: “failing to balance risk, additional public-sector requirements, stifling or not applying innovation, selection of construction specifications, and parameterization of the execution process.” The report concluded that “government application of DB does not match the private sector DB in terms of procedures or benefits; the government, as the owner and construction agent, remains heavily involved in the process” (Blomberg et al., 2014).

Design-Build within USACE
Although the highlighted studies indicate mixed benefits and disadvantages to using Design-Build, the regulations are in-place to facilitate this project delivery method, and DB has become a viable, common option for USACE project delivery. The study of federal highway projects indicates that DB can provide schedule reduction when compared to DBB, but is inconclusive in terms of cost and quality consequences. Rosner et al., provides that DB Air Force MILCON creates fewer modifications and improves overall cost. And finally, Blomberg et al., concludes that Design-Build effectiveness does not necessarily depend on the selection of project delivery method, but more-so on the executing construction manager. Thus, in order to ensure the benefits of Design-Build, the military construction agent (USACE among others), must ensure their execution of the DB process is not encumbering to the DB contractor selected for the job.
5.1.3. Construction Management at Risk

Construction Management at Risk (CMAR) is defined as project delivery using two separate contracts. The first, is a design contract between the owner and a selected architect & engineering (AE) firm, and the second, a consulting and construction contract with the Construction Manager at Risk (CMAR) (Primer on Project Delivery, 2011). Similar to DBB, the owner provides requirements to a selected AE firm, and maintains the fiduciary relationship with their selected designer through a contractual agreement. But early in the design process, or potentially from the onset, the owner selects a CMAR contractor with the requisite experience and capacity to provide pre-construction consulting services for the design phase, including but not limited to: cost estimation, constructability analysis, value engineering opportunities, schedule development, and material selection (Farnsworth et al., 2016). At approximately 50% to 75% through the detailed design phase, the CMAR generally negotiates with the owner on a bid for the project construction (Kwak and Bushey, 2009). Typically, the owner and CMAR agree on a Guaranteed Maximum Price (GMP) for the project which includes materials, labor, overhead, profit, and a contingency portion to be returned to the owner if unused. While the practice of negotiating a GMP is common for CMAR, it is not required, and the creation of the GMP should be a developing process between the owner, designer, and CMAR through the planning phase (Farnsworth et al., 2016).

Description
The intent of the Construction Management at Risk project delivery method is to enable the owner to gain efficiencies through enhanced collaboration and early engagement between the AE firm and CMAR, without losing the entrusted obligation of the project architect to the owner. As opposed to a purely consulting obligation, the Construction Manager is considered ‘at risk’ because the "contractor holds the trade contracts and takes the performance risk for construction" (Primer on Project Delivery, 2011). The owner is responsible for hiring the AE firm under a separate contract, and for swiftly selecting a CMAR based on past performance, qualifications, and fee agreement, in order to maximize the collaboration benefits during pre-construction. The AE firm meets design requirements, and works with the owner and CMAR to produce high-quality, constructible plans within schedule and budget. The CMAR provides pre-construction consulting services, develops the GMP bid, hires subcontractors, and “takes on the financial obligation for construction under a specified cost agreement.” The CMAR structure is
shown in Figure 5.5., and highlights the collaborative relationship between designer and contractor, as well as the owner’s typically heightened influence on subcontractor selection.

Advantages and Disadvantages
Potential advantages for CMAR include: greater synchronicity throughout the design and construction timeline; fast-tracking opportunities; creation of fewer conflicts between the parties involved; cost, schedule, and quality benefits from a more cohesive and agreed-to project plan; and reduced risk through promoting an integrated approach to problem solving (Farnsworth et al., 2016). The possible disadvantages of the CMAR project method include: unknown total cost and schedule at the point of hiring the Construction Manager; over-reliance on the Construction Manager entity to provide consulting services, bidding/cost expertise, and project construction management; and reluctance for unfamiliar firms to adopt/embrace the collaboration component of CMAR (Gordon, 1991).

A thorough analysis of CMAR advantages was conducted in 2010, and covered 19 public agency representatives with a total value of CMAR-executed projects in excess of $2.3 billion (Shane and Gransberg, 2010). Their literature analysis coupled with expert interviews found five distinct advantages for applying the CMAR project delivery method: “the ability of the constructor to make substantive/beneficial input to design, the enhanced ability to accelerate the project’s delivery schedule, enhanced cost certainty at an earlier point in design than DBB, the ability to bid early work packages as a means to mitigate the risk of construction price volatility and accelerate schedule, and owner control over the details of design.” The most frequently cited advantage through their interviews and literature review identified ‘CMAR input to design’ as the critical element contributing to value for this delivery method.
Construction Management at Risk for Transportation Infrastructure Projects

A 2016 study analyzed the effects of CMAR project delivery in the public transportation sector, using a sample of 51 total CMAR contractors, owners, and designers from construction companies, public agencies, and engineering design firms (Farnsworth et al., 2016). Their study surveyed individuals to identify perceived benefits and disadvantages to executing CMAR projects, and to compare CMAR to DB and DBB in six risk categories: quality, constructability/design, project schedule, construction cost, added cost reduction, and adaptation to change. Their findings indicated that roughly 55% of all interviewed respondents (Figure 5.6.) felt that CMAR was beneficial to managing process risk associated with quality. However, nearly 50% of those respondents felt the CMAR project method was a disadvantage in dealing with cost risk and roughly 30% felt it was a disadvantage to collaboration and flexibility risk (Figure 5.7.).

Figure 5.6. ‘Benefits’ of managing risk with CMAR (Farnsworth et al., 2016)

Figure 5.7. ‘Disadvantages’ of managing risk with CMAR (Farnsworth et al., 2016)
The surveyed respondents conveyed that CMAR project delivery did not necessarily resolve the process risk factors, but in comparison to the DBB and DB project methods, it was viewed more favorably (Figures 5.8., 5.9., and 5.10. for quality, schedule, and cost). Considering the aforementioned six risk factors, CMAR was preferred over DBB in nearly every category (Farnsworth et al., 2016). But, when compared with DB project delivery, responses varied between owners, contractors, and designers, and between each risk factor. In summary, the research showed that CMAR was insufficient for resolving all process risk concerns and different professions valued DB and CMAR differently. But overall, the CMAR project delivery method was considered more adept at addressing the project risk factors than the traditional DBB method.

Figure 5.8. Ability of CMAR to improve project quality (Farnsworth et al., 2016)
Figure 5.9. Ability of CMAR to control project schedule (Farnsworth et al., 2016)
Figure 5.10. Ability of CMAR to reduce construction costs (Farnsworth et al., 2016)
CMAR vs DBB for Public School Construction

A similar study evaluated the CMAR project delivery method for public school construction in the southeast United States. It evaluated 137 school construction projects across Florida, Georgia, North Carolina, and South Carolina from 2012 to 2014. CMAR projects represented 37% of their sample and DBB represented 63% (relative ratios to the U.S. commercial sector’s use of CMAR). The study conducted statistical analysis of the two groups using t-tests to compare costs and durations, as well as a qualitative ratings assessment. The size and capacity comparison between DBB and CMAR projects resulted in nearly identical project scope averages in gross project size and student capacity per area, thus signaling that the DBB and CMAR projects were compatible in scope (Carpenter and Bausman, 2016).

Despite equivalent scope requirements, the CMAR final construction costs were $27.4 million per project on average, compared to the DBB final cost of $22.4 million on average. Thus, the average CMAR project cost $5 million or 22% more to produce an equivalent school to the DBB method, corresponding to a statistically significant p-value of 0.025. The study’s evaluation of duration statistics did not produce any significant findings as both methods were nearly equal in average execution timelines. In terms of quality however, the survey data showed significant improvements in using CMAR over DBB, with p-values indicating CMAR superiority in product quality, construction team service, design team service, and project team service. As the report summarized: “evidence supports the foundational research and theoretical construct that collaborative environments have the ability to positively influence the product and service quality of construction projects. Conversely, the cost performance results indicate that the collaborative properties of the CMAR method were not capable of controlling or reducing cost, time, or risk (claims) on these projects” (Carpenter and Bausman, 2016). In essence, the builders of public schools that were choosing the CMAR delivery method were achieving greater quality on average, but at a price premium of 22% more per project over DBB.

Impediments to CMAR in Water and Wastewater Treatment Infrastructure Projects

As discussed in the transportation industry and public-school construction sector, there are disadvantages and advantages to selecting CMAR as the project delivery method. But nearly every study highlighted a common struggle to implement the unique delivery technique with an unfamiliar (and sometimes unaccepting) project team. In 2016, a study specifically explored the topic of impediments to alternative delivery for Water and Wastewater Treatment projects, including barriers to implementing CMAR. With 104 survey respondents from 32 states, the
sample included utility managers, project staffs, and policy officials in the water and wastewater sector. Of those surveyed, 76% noted internal obstacles to implementing alternative delivery projects including: “unfamiliarity with the process by management, senior staff, or policy officials, and resistance to change within management or policy officials” (Shrestha et al., 2016). To compound the delivery method selection struggle, 67% of survey respondents cited additional external factors influencing alternative project delivery, including: “state procurement statutory requirements, municipal or agency procurement regulations, and other impediments.” Despite the many obstacles, respondents provided a litany of suggestions for improving alternative project delivery awareness and implementation strategies to enable states and municipal governments to capitalize on CMAR project delivery benefits.

**Construction Management at Risk within USACE**

While not a common form of project delivery in USACE, the elements of the CMAR delivery method are present in several ongoing and completed projects across the country. Referred to as IDBB (Integrated Design-Bid-Build) or as ECI (Early Contractor Involvement), USACE applies some of the tenets of CMAR while adhering to the regulations of the FAR. USACE provides Engineering and Construction Bulletin 2009-04 (2009) pertaining to the authorization and implementation of the ECI delivery system for Military Construction and Civil Works projects. It specifies, the “ECI delivery system is a DBB delivery system procured using an options contract” or “FAR 16.403-2 Fixed-Price Incentive (Successive Targets) contract.” As discussed in a case study by Rich and Bartha (2012), USACE selection of “ECI is most appropriate in cases where a commercial construction project would use CMAR; a complex ‘one of a kind’ project with no standard design, an aggressive no-fail project schedule, a customer that wants to shape design, and a challenging site or other unique aspect of a project.”

In July of 2015, the Associated General Contractors of America met with top officials from USACE HQ, Naval Facilities Engineering Command (NAVFAC) HQ, and the GSA to discuss ECI implementation strategies moving forward. USACE conducted several ECI pilot projects throughout the 2000’s concentrated near the Kansas City District, but the trend has since fallen off. Likewise, NAVFAC conducted an ECI pilot program which was eventually discontinued (Associated General Contractors of America, 2015). Each government agency experiences the rising cost and schedule growth of federal infrastructure projects, and thus, continues to explore alternative options to delivering projects with greater efficiency and quality.
5.1.4. Public Private Partnerships

Likely the most complex of the project delivery methods, Public Private Partnerships (P3s) are also the most controversial. P3s go by many names and constitute several different arrangements of relationships between public owners and private concessionaires. For the purpose of this research, P3s most nearly align with the Design-Build-Operate-Transfer (DBOT) model where a private organization designs and builds infrastructure to meet a government entity's requirements, finances the construction and long-term operation of that infrastructure, and operates and maintains the project for an agreed-upon duration. As repayment, the private organization receives concessions, generally in the form of tolls, tariffs, or set payments, and after the completion of the concession period, the infrastructure is returned to the government (Gordon, 1991; Levy, 2008). Several variants arise from this project delivery and contracting concept, including: Build-Own-Operate, Lease-Develop-Operate, Availability Payment Process, and Long-Term Leasing (Levy, 2008). Unlike the traditional delivery structures, that are universally accepted methods, P3 is not a valid project delivery method in many parts of the country because several state legislations do not legally allow the contractual relationship (as shown in Figure 5.11.). Nevertheless, of the 37 states that authorize private investment in public infrastructure, $46 billion was spent on P3 transportation infrastructure projects from 1990 to 2010 (National Conference of State Legislatures, 2015).

Figure 5.11. 37 U.S. States have enabling P3 legislation (Boerboom and Dodds, 2017)
Description
P3s are executed more prevalently in the global market as a way to infuse public infrastructure with private investment. Domestically, they are sometimes referred-to as privatization, where public entities pay private companies to execute projects including highways and prisons (Gordon, 1991). Often, the private organization is a consortium of companies providing the services of design, construction, operational management, and financing expertise. As with other delivery methods, the owner interested in a P3 contract benefits from a competitive bidding process, and generally initiates the project with a conceptual design and defined requirements. The “private consortium builds a project to meet a government agency’s requirement and provides complete design or augments an owner’s design development” (Levy, 2008). Furthermore, “the consortium finances, constructs, operates, and maintains the facility during a specified concession period.” Compared to traditional methods, P3 projects require significant contracting beyond the initial scope of design and construction. The owner and private consortium must consider the following: initial public investment amounts, the economic analysis to determine the net-present-value of the tolls or tariffs, the politically acceptable tolling rates, the length of duration for economic feasibility, the perception of the public, the acceptable return on investment for the private organization, the maintenance schedule of the infrastructure, and potential resale value at the end of duration. The organization structure of the P3 is shown in Figure 5.12.

Advantages and Disadvantages
Advantages of the P3 method include: the reduction in required investment capital, the project’s tendency to meet budget and schedule, the reallocation of risks from the government to private investors, the reduced lifecycle expenses for the public entity, and the enabling of public
agencies to reallocate resources of time and money elsewhere (Papajohn et al., 2011). Additionally, advocates for P3’s cite the infusion of private technology into public projects, the building of infrastructure with reliability and maintainability in-mind, the delegation of complete site responsibility away from the government owner, an agreed-upon cost and schedule for initial construction delivery, and enhanced teamwork within the cohesive private team (Gordon, 1991). Disadvantages include: potential bail-outs by the public entity, varying ownerships and incongruent tolls within a region, diversion of public away from tolled or tariffed infrastructure, and public skepticism of private company motivations (Papajohn et al., 2011). Additional hurdles include the lack of general experience and knowledge with this delivery method, political and legislative barriers to execution, owner loss of flexibility and control on the project delivery, and the over-reliance on a single consortium to execute the long-term project (Gordon, 1991).

**P3 Delivery Method for Port Projects**

A 2001 study examined the potential for P3 project delivery for federal port construction. The report highlighted three major situations that favor the utilization of P3 delivery methods: “funding shortfalls and the conservation of bonding capacity, projects outside of the port’s geographic jurisdiction, and non-maritime economic development” (Ritchie, 2001). Import and export trade represented a growing portion of the nation’s GDP (30% in 1996), and the value of U.S. trade increased dramatically from 1970 to 1998 ($84 B to $1.5T, or a growth multiple of 19). U.S. ports accounted for 95% of that trade by volume, and 75% by value, and in order to meet increasing demands, port infrastructure required significant investment. Ritchie identified four key factors that are critical to the success of P3 projects: “a revenue stream capable of retiring the project debt,” an “entrepreneurial public-sector participant,” a “predictable public process,” and “committed participants willing to solve problems as they arise.” Lastly, he noted a significant advantage for owners interested in P3s was the distribution of risks to the P3 entity as shown in Figure 5.13. While the owner took-on increased political risk, the P3 entity shouldered much of the design, engineering, schedule, financial, and operational burdens.
### Figure 5.13. Public Private Partnership Distribution of Risk (Ritchie, 2001)

**P3 Delivery Method for Transportation Projects**

Many prevalent studies of Public Private Partnerships involved the transportation industry, as the federal highway system quickly became a hub for P3 project execution. In a survey sent to every state’s department of transportation, 12 states had actively executed P3 projects, and 14 additional states planned future P3s (Papajohn et al., 2011). Eight states had no plans to implement future P3 transportation projects, and not surprisingly, those states were geographically located in the north and northwest with some of the least congested traffic environments. The survey also requested the primary reason for implementing P3s, a general satisfaction rating with the P3 delivery method, and whether the P3 projects were on schedule and within budget. Generally, the states adopted P3 projects for financing support, and the satisfaction ratings and cost/schedule evaluations were quite favorable as shown in Figure 5.14. Lastly, a study by the National Audit Office in 2003, determined that 24% of P3 projects were delivered late compared to 70% of projects delivered conventionally, and 22% of P3s had cost overruns in comparison to 73% otherwise. The study indicated that private consortiums committed for long-term operations and maintenance produced high-quality projects that generally met delivery schedules.
Critical Success Factors for P3s
Zhang (2005) examined critical success factors (CSFs) for implementing P3s. While a combination of factors contributes to a project’s success or failure, the study intended to determine the CSFs with the greatest influence, through a literature review and subject matter expertise testimonials. Zhang noted that while P3s have seen success internationally, serious issues and several P3 failures can be linked to the broad-range of risks associated with P3s, the multi-party approach to P3 execution, and general unfamiliarity with executing P3s. The literature review established 47 success sub-factors and categorized them under 5 CSFs: “economic viability, appropriate risk allocation via reliable contractual arrangements, sound financial package, favorable investment environment, and reliable concessionaire consortium with strong technical strength.” The 46 respondents came from international organizations from both industry and academia, and rank-ordered the CSFs as listed above. Key to a “favorable investment environment” were the sub-factors of “stable political system” and “government support,” which seemed appropriate considering the failure of some international P3s by forced government nationalization. The most prominent success sub-factor selected by the respondents was the “long-term demand for the project service” and its contribution to “economic viability.”

Failure Trends in P3s
Inversely to analyzing P3 success factors, Soormo and Zhang (2016) evaluated P3 transportation project failures to determine key mechanisms that caused a project’s demise, and
where in the process they occurred. They analyzed 35 project failures that met at least one of the following criteria: “value for money not achieved, concession cancelled, concession tender cancelled, project nationalization, project halted, or contract suspension.” Notable project failures included the cancelling of toll concessions for the Mexico Toll Road Program, the nationalization of the California 91 Express Lanes, and the closure of the Camino-Columbia Toll Road in Texas. They found that the public sector contributed to 27 different failure mechanisms resulting in project failure, to include: inadequate technical feasibility assessment, poor economic & financial feasibility assessment, vague contract descriptions, and ineffective project monitoring, to name a few. Conversely, private company insolvency was the major failure mechanism solely attributed to the private consortiums. They concluded that the project feasibility and procurement stages were the most critical periods for P3 failures, given the majority of failure mechanisms occurred during those phases.

Public Private Partnerships within USACE

The studies outlined above provide relevant indications of the advantages and disadvantages of implementing P3 projects. While some states have found success in P3 toll highways, the legislation for comprehensive P3 national infrastructure services does not yet exist, as not all state constituents want private investment. Ritchie’s study of port projects exemplifies the shifting of financial, design, construction, and operational risks to the P3 organization, but with that reduction of risk comes a loss of project control and an increase in political contention. As the Soormo and Zhang research shows, political friction and a number of economic destabilizers can trigger failure mechanisms, especially in the early feasibility and procurement phases of a P3. While these studies address P3 projects and policies that are ongoing efforts between private and public entities, the industries do not directly reflect the business lines of the Corps of Engineers. Furthermore, as of 2017, the Corps of Engineers has not yet executed a P3 project to completion, so the organization has the added barrier of forging original P3 policy.

In June of 2013, the USACE Institute for Water Resources commissioned external consultants to lead alternative funding workshops and develop a report outlining an alternative finance way-ahead for the Corps (U.S. Army Corps of Engineers – Institute for Water Resources, 2013). The report recognizes multiple long-term funding strategies, including: revenue enhancement through user fees; Trust Fund dedication; value capture through taxation of provided services or projects; and asset sales, transfers, or dispositions. The Water Resources Reform and Development Act of 2014 authorizes a P3 Pilot Program for execution through USACE. While
still in the exploratory phase for USACE project delivery, recent discussions of private investment into national infrastructure have increased the interest of P3 project delivery for the Corps of Engineers. In a December 2016 interview, the Chief of Engineers stated that USACE is “researching how public-private partnerships might improve value for money by creating incentives for best-practice design, timely completion, and efficient operation by sharing project risk with the private sector” (Defense Media Network, 2017). As of late 2017, several USACE projects are in consideration for P3s and regulatory guidance is in progress at the USACE Headquarters level.

The USACE program most interested in P3s is the Civil Works line of effort, and projects for new construction as well as large maintenance contracts are in consideration for P3 eligibility. While P3s are a relatively common practice in certain infrastructure domains, the lack of state and federal legislation authorizing P3s creates a barrier for USACE to implement the project delivery strategy at the national level. In January 2017, the Harvard Kennedy School – Ash Center held a symposium to address private financing in federal water infrastructure projects. The report, *Tapping Private Financing and Delivery to Modernize America’s Federal Water Resources* (Goldsmith and Jamieson, 2017), acknowledges several challenges and constraints addressing P3s for federal water infrastructure projects, but recommends multiple strategies for navigating the funding and policy hurdles. Of note, the report addresses four critical actions that must be taken to enable federal water infrastructure P3s: “enable revenue generation and ring fencing, enable budget-based compensation structures, further enable non-federal public-public private partnerships, and create an appropriate P3 enabling framework.”
5.1.5. Integrated Project Delivery

Integrated Project Delivery (IPD) is by-far the least implemented project delivery method discussed in this thesis. As a relatively new project method, there is much uncertainty revolving around its acceptance. IPD requires a “multiparty agreement among the prime players in the design and construction process,” to include, at a minimum, the owner, architects, engineers, general contractor, and often, select consultants and subcontractors (Construction Management Association of America, 2012). Establishing an extremely collaborative environment from the onset of the project is crucial to IPD success, and although many private companies may not feel comfortable with the multi-party agreement, some organizations think that IPD reflects the innovative future of the industry. Furthermore, to implement IPD successfully requires a commitment by all to the extensive use of Building Information Modeling (BIM) and collaborative software.

A joint convention of construction industry leaders met in 2010 to collaborate on an IPD guide for public and private owners. Members of the National Association of State Facilities Administrators (NASFA), Construction Owners Association of America (COAA), APPA: The Association of Higher Education Facilities Officers, Associated General Contractors of America (AGC), and American Institute of Architects (AIA) discussed that construction projects generally met three tiers of collaboration: 1) no contractual requirement, 2) some contractual collaboration required, and 3) collaboration required through a multi-party contract (Integrated Project Delivery: For Public and Private Owners, 2010). The report indicated that most members of the construction industry were predominantly familiar with option 1 – no contractually required collaboration, which contributed to waste and a lack of productivity. Furthermore, the impetus for driving the IPD change included “technological evolution and owner demand for value.” A 2004 National Institute of Standards and Technology study determined that the construction industry lost roughly $16 billion annually due to lacking software interoperability. The AIA-AGC Project Delivery Primer reflected that as building construction becomes increasingly more complex, greater collaboration was required amongst construction service providers, and a “best-for-project” mentality was crucial to project success (Primer on Project Delivery, 2011).
Description
IPD requires a “contractual arrangement among a minimum of the owner, constructor, and design professional that aligns business interests of all parties” (Primer on Project Delivery, 2011). The contract ties the stakeholder success to the success of the project and requires a list of contractual principles, namely: equality among parties, shared financial risk and reward, liability waivers, fiscal transparency, early involvement, jointly developed project targets, and collaborative decision making. From the American Institute of Architects, California Council (2007): “IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication, and construction.” As described, the owner, designer, and builder are requisite members of the IPD team, and a potential IPD structure is shown in Figure 5.15.

![Figure 5.15. Integrated Project Delivery Structure](image)

Advantages and Disadvantages
Advantages of IPD include: collaboration among all parties, ability to fast-track project, pre-construction service expertise from general contractor, aligned team interests in project, enhanced synchronization between design and construction, distribution of risk among all parties, open-book compensation and incentives, and potentially reduced waste and enhanced productivity from collaborative software use. Disadvantages of IPD include: unfamiliarity by many firms with executing IPD, little-to-no legal precedents for resolving disputes, extensive time and money spent on establishing the contract, importance of team dynamics and behavior characteristics, objective selection of team without a competitive bidding process, and complexity of the entire contract process.
Evaluation of IPD Using a Project Quarterback Rating (PQR)

El Asmar et al. (2016) assessed different project delivery methods using a standard rating system similar to the concept of the NFL quarterback rating (an overall comparison number based on four criteria: touchdowns, interceptions, completion percentage, and passing yards). They argued that nearly every construction study over-emphasized cost and schedule without addressing other critical aspects of project delivery. For their PQR, they conducted a literature review and established seven assessment criteria: customer relations, safety, schedule, cost, quality, financial metrics, and communication/collaboration. To weight the criteria, the team surveyed 34 industry practitioners to determine the most important performance metrics, and to create the normalized PQR formula (Figure 5.16.).

![Figure 5.16. Performance Area Importance and PQR Formula (El Asmar et al., 2016)](image)

Through factor analysis, the team determined that only three factors contributed to variance, and thus, reevaluated the PQR formula to include: the cost factor; the schedule factor; and the quality, communication, and business factor (El Asmar et al., 2016). The PQR formula provided a comprehensive project performance metric and was validated against independent techniques. PQR was then used to compare other project delivery methods, as shown in Figure 5.17., and IPD showed consistent overall superior performance in comparison to traditional methods.
Performance Metrics for IPD
Hannah (2016) used a similar PQR method to analyze IPD and near-IPD projects with respect to communication, change management, and business performance. Near-IPD project delivery included many of the concepts of IPD, but not necessarily with the contractual obligation. IPD for Public and Private Owners (2010) referred to near-IPD as executing IPD Philosophies with CMAR or DB. Hannah (2016) analyzed a sample of projects from 42 professionals accounting for over $1.5 billion in construction projects, including IPD/near-IPD and non-IPD construction. The two categories of project delivery were compared using three metrics: RFIs per million dollars of project, change-order processing time, and potential for return business. The IPD project delivery methods outperformed non-IPD in each of the evaluated metrics as shown in Figure 5.18. Additionally, Hannah evaluated the sample projects with the PQR rating and found similar preferred overall results for IPD. Hannah concluded that "projects using IPD, or a large amount of IPD principles, have superior performance in changes, business, and communications areas."
IPD in the Public Sector

Collins and Parrish (2014) stated that IPD focuses stakeholders by “addressing the three common domains of project delivery systems: project organization, operating system, and commercial terms binding the project participants.” They noted that even with the rise of Design-Build and Construction Management at Risk, the Construction Users Roundtable urged the industry and owners to demand further-integrated delivery systems, and the IPD concept was formed in the mid-2000’s. However, federal and state contracting regulations continued to limit the widespread use of IPD for public construction. They argued that the collaborative team assembled in IPD was superior in meeting owner requirements and reducing costly construction change orders. An assessment of change orders at a public university over twelve years of
construction showed that roughly $21 million was spent on change orders from original contracts worth $196 million (10.7% over the planned expenses). While IPD was still largely untested, especially in the public sector, they argued that industry needs to invest in solutions that limit waste and reduce unforeseen change orders.

**Integrated Project Delivery within USACE**

As the studies outline, the collaborative effort of Integrated Project Delivery likely improves many aspects of cost, schedule, quality, and relationships during the construction process. As El Asmar et al. and Hannah display, IPD and near-IPD projects perform well against their traditional delivery method counterparts. Collins and Parrish identify the high-cost of change orders as a driving influencer for IPD. They propose that if a public agency is already spending 11% on top of contractual expenses for unforeseen change orders, perhaps the agency should invest that money into achieving a more collaborative system. The tenets of IPD are well-intentioned: collaboration, risk sharing, joint incentives, liability waivers, improved relationships, cooperative decision making, waste reduction, and technology infused communication. But despite these advantages, the U.S. public construction sector is still untested and often restricted by regulations from executing pure-IPD project delivery.

Notwithstanding, the AIA IPD Guide provides advice on implementing IPD concepts with traditional delivery methods, although integration problems are forewarned. The guide states that “IPD principles can be applied to a variety of contractual arrangements and IPD teams will usually include members well beyond the basic triad of owner, designer, and contractor” (American Institute of Architects, 2007). For USACE, near-IPD philosophies are likely the avenue for exploring this alternative project delivery method. CMAR projects provide an opportunity for an owner to execute IPD tenets as the Construction Manager is brought-on early and is poised to assist the design team. The general hurdle for CMAR/IPD integration is that the owner must still maintain two separate contracts (designer and CMAR). Design-Build also offers some potential for near-IPD integration. The DB contract is already a collaborative effort between the Design-Builder and a hired AE firm. The greatest hurdle for DB/IPD integration is in the risk and roles of the owner. Most owners select DB to shift risk to another entity, and this runs contrary to enhanced owner involvement in the IPD. While pure IPD systems may not be forthcoming for USACE, the tenets of IPD provide a foundation for teamwork and collaboration for any project delivery team.
5.2. Project Drivers and Project Delivery Method Matrix

Given the literature review and an understanding of traditional USACE project delivery methods (DBB and DB) and alternative project delivery methods (CMAR, P3, and IPD), this section provides a succinct resource to organize the benefits and disadvantages for selecting each. A number of ‘project drivers’ are identified to distinguish between the project delivery methods, and Figure 5.19. displays the comparisons in matrix form. The matrix provides a resource for USACE project managers or industry practitioners that are unfamiliar with the alternative project delivery methods.

Diversification of Project Delivery Methods

As shown in Figure 5.19., a variety in project delivery methods provides opportunities and flexibility for USACE Districts and Project Managers to reduce risks and manage project cost and schedule. As shown, various Project Drivers should be considered when planning an alternative method for executing a construction project. Additionally, Market Drivers, Owner Capabilities, and Legal Regulations all contribute to the decision to select a specific acquisition strategy. Each method provides benefits and disadvantages, and a flexible acquisition strategy allows the PM to tailor project delivery to specific infrastructure needs.

Selection of the project delivery process must also consider the market of available resources, qualified designers and contractors, the construction project difficulty, expediency, and advanced technical requirements. Specified BIM requirements and other construction technology might also be a factor for selecting alternative project delivery methods over traditional approaches. Considering CMAR, P3, or IPD project delivery provides the Corps of Engineers with greater flexibility to address the array of project missions that USACE executes. While USACE predominantly selects traditional DBB or DB project delivery, the Chief of Engineers’ statements, USACE involvement in innovative infrastructure symposiums, and the Congressionally authorized P3 Pilot Program are all indications that the agency is moving to incorporate alternative project delivery methods.
<table>
<thead>
<tr>
<th>Project Drivers</th>
<th>Design-Bid-Build (DBB) “Traditional Method” “General Contractor”</th>
<th>Design-Build (DB)</th>
<th>Construction Manager at Risk (CMAR) “CM@R”</th>
<th>Public Private Partnership (P3) “Build Operate Transfer” “Long-Term Leasing”</th>
<th>Integrated Project Delivery (IPD) “Near-IPD” “IPD-ish”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to Fast-Track Schedule</td>
<td>No</td>
<td>Possible</td>
<td>Yes</td>
<td>Possible</td>
<td>Yes</td>
</tr>
<tr>
<td>Cost and Schedule for Project Known</td>
<td>At GC Bid</td>
<td>At DB Bid</td>
<td>After CMAR Hired, ~50-75% Through Design</td>
<td>At P3 Bid</td>
<td>Negotiated into Contract at Onset</td>
</tr>
<tr>
<td>Pre-Construction Services</td>
<td>No</td>
<td>Possible</td>
<td>Yes</td>
<td>Possible</td>
<td>Yes</td>
</tr>
<tr>
<td>Project Flexibility/Owner Control</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Lowest</td>
<td>Highest</td>
</tr>
<tr>
<td>Design Fiduciary</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes, by Committee</td>
</tr>
<tr>
<td>Competitive Bidding Process</td>
<td>Yes</td>
<td>Yes</td>
<td>No, CMAR Selected Early Based on Qualifications</td>
<td>Yes</td>
<td>No, Team Selected Early Based on Qualifications</td>
</tr>
<tr>
<td>Enhanced Collaboration</td>
<td>Lowest</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Highest</td>
</tr>
<tr>
<td>Project Financing</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Legal/Political Precedent</td>
<td>Yes</td>
<td>Yes</td>
<td>Some</td>
<td>Depends on State</td>
<td>No</td>
</tr>
<tr>
<td>Owner Responsibility</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Lowest</td>
<td>Highest</td>
</tr>
<tr>
<td>Method Familiarity</td>
<td>Highest</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Lowest</td>
</tr>
<tr>
<td>Public Response</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Mixed/Often Negative</td>
<td>Neutral</td>
</tr>
<tr>
<td>Contracting Difficulty</td>
<td>Lowest</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Figure 5.19. Project Drivers & Project Delivery Methods Matrix (Gordon, 1991)
Chapter 6. Case Studies of Alternative Project Delivery in the Public/Private Sectors

The following case studies exemplify two projects where USACE explores alternative project delivery, and another where private agencies apply a fundamentally new delivery strategy.

Fort Belvoir Community Hospital
Under an 'Integrated Design-Bid-Build' approach, the Fort Belvoir military installation and medical community, and the USACE Norfolk District executed a CMAR project for a world-class on-post medical center. This project provides a real-world application of CMAR by USACE, with an award-winning final product and prolific lessons-learned. The flexible CMAR delivery enabled extreme fast-tracking of the project, while also meeting the extensive and evolving requirements of the medical community. Though the quality is highly revered, the project experienced extensive budget over-runs. The case study provides implementation guidance, lessons learned, and USACE applications for CMAR.

Fargo-Moorhead Flood Risk Management
The Fargo-Moorhead Flood Risk Management civil works project by the St. Paul District represents the first USACE attempt to complete a P3. This case study discusses the background, need, and criticality of the Fargo-Moorhead project. Part of the ‘P3 Pilot Program’ included in the Water Resources Reform and Development Act of 2014, the Fargo-Moorhead Area Diversion project is USACE’s first ‘Demonstration Project’ to determine the viability of the P3 method. While still in pre-construction, and without a selected P3 partner as of late 2017, the project has experienced an array of technical, political, and legal challenges.

AutoDesk Inc. AEC Solutions Division Headquarters
Although USACE has not yet engaged in Integrated Project Delivery, the case study for AutoDesk Inc. highlights a pure-IPD project delivery with some of the New England region’s most forward-thinking practitioners of BIM and IPD. The AutoDesk project provides a private-industry example of the benefits of extensive collaboration and the application of BIM technologies and pure-IPD project delivery. The owner, designer, builder, and key sub-contractors were contractually and legally bound to the project and likewise shared all the project risks and rewards. While the mechanics of the IPD contract and liability waivers are ill-suited for USACE, the philosophy of the IPD method includes valuable lessons learned in collaboration, team management, and early contractor involvement.
6.1. Construction Management at Risk: Fort Belvoir Community Hospital

The 2005 Base Realignment and Closure (BRAC) Commission, a panel of independent professionals appointed by the President and with consent from the Senate, outlined an aggressive modernization of the Military Health System (MHS), including the closure of Washington, D.C.’s historic Walter Reed Army Medical Center (opened in 1909) and the Fort Belvoir Dewitt Army Community Hospital in Virginia (opened in 1957). The BRAC Commission determined that both hospitals would be closed no later than 2011, and a replacement hospital would be built on Fort Belvoir to accommodate a significant portion of the region’s military medical needs. The new medical center required nearly 1.3 million square feet of facilities, and a military hospital of that scale generally took 10 years from concept to occupancy. But, the BRAC Commission required the world-class medical center to be operational within 5 years, and thus, the U.S. Army Corps of Engineers sought alternative project delivery options to execute the fast-tracked project. Not only was the project time-constrained, but the Fort Belvoir Community Hospital represented the Army's first hospital replacement of seven major medical center projects, ushering-in an immense undertaking of military medical modernization. With lofty expectations from several stakeholders for ‘World Class Standards,’ and its close proximity to the nation’s capital, the Fort Belvoir project was both massive in scope and heavily watched.

Title: Fort Belvoir Community Hospital
Location: Fort Belvoir, VA (20 miles south of Washington, D.C.)
USACE: Norfolk District, North Atlantic Division
Client: Army Medical Community and Fort Belvoir Garrison
Architects: HDR Architecture, Inc. and Dewberry Joint Venture
Contractors: Turner Construction and Gilbane Building Company Joint Venture
Cost: $1.2 billion
Schedule: 5 years
Key Deliverables: Meet the rigid 5-year delivery schedule, deliver ‘World Class Standards,’ include ‘Evidence-Based Design,’ achieve LEED-Silver rating, and provide a modernized military medical facility to serve Wounded Warriors and the hundreds of thousands of active and retired service members and their families in the region (Norfolk District, 2010).
Project Description
Once the 2005 BRAC Commission proposals were approved by the President, the recommendation was pushed to Congress to enact the proposal, approve funding, and determine the execution schedule. Once allocated funding, USACE began the official design and construction process. Specified as 'Integrated Design-Bid-Build (IDBB),' the project delivery method utilized for the Fort Belvoir Community Hospital mirrored similar delivery strategies used in the private sector (Early Contractor Involvement or Construction Management at Risk). The undertaking was so large and time-sensitive, that the Corps quickly determined the need for a Joint Venture and split project responsibilities for design.

The project design required a medical complex with multiple structures, ample parking, a utilities plant, and environmentally friendly landscaping and features. The main hospital building included 10 operating rooms, 30 emergency rooms, 10 intensive care unit rooms, an emergency center, a behavioral health unit, a cancer center, and a Level II nursery (Turner Construction, 2017). Four outpatient clinics extended off the hospital, with intermittent courtyard gardens between buildings. The “swooping rooftops on the outpatient clinics” were a signature element of the design (Figure 6.1.) that “reflects the pristine natural setting,” and “evokes the image of nearby Mount Vernon” (Healthcare Design, 2008).

The facility emphasized aesthetic appeal, but most of the features were also part of the energy reduction plan or Evidence-Based Design (EBD). EBD guided many elements of the design process using the following principles: “create a patient and family centered environment, improve the quality and safety of healthcare, and enhance the care of the whole person” (Healthcare Design, 2008). While features such as enhanced natural light exposure and single-patient rooms increased user satisfaction, they also affected the morale of the family or recovering patient, and contributed to better sleep and faster recovery. In addition to EBD targets, the design team also focused on LEED (Leadership in Energy and Environmental Design) certification and benefits. The medical center rooftops fed a rainwater screening and cistern system that irrigated the surrounding property and led to a reduction in water use. The facility also incorporated green roofs, permeable paving, increased recycling, energy efficient systems, and a heat-recovery chiller system for reheating (Medical Construction and Design, 2012). While the project team sought LEED-Silver during planning, the Fort Belvoir Community Hospital was eventually certified as LEED-Gold, the largest hospital to accomplish that certification as of 2012.
The Fort Belvoir Community Hospital was one of the Army’s largest hospitals and was referred to as the “New Model for Modern Military Healthcare” (Gilbane Building Company, 2017). To deliver this mammoth and specialized project, the Norfolk District also employed a Joint Venture to complete the construction. The Turner-Gilbane Joint Venture was awarded the contract in September of 2007, and their personnel immediately began the process of informing and improving the design” (Muhlenkamp, 2012). Within a few months, the builder and designer were collocated and before long, the selected sub-contractors were also incorporated into the ‘design-assist’ planning meetings. “Having selected a steel moment frame system, the work of the structural engineering and the steel sub-contractor and detailing teams ... became the focus of some of the very first design-assist meetings.” Although the design was still in-progress, the collaboration between designer, builder, and sub-contractor enabled the early acquisition of steel orders from the mill, and as the project evolved, that collaboration was replicated for several other disciplines. USACE’s application of IDBB and early integration of the construction Joint Venture allowed for initiating site work in January of 2008, a year and a half before the design was 100% complete (Norfolk District, 2010).

Elements of CMAR/IDBB for the Fort Belvoir Community Hospital
Evaluating the decision to apply IDBB, the USACE Norfolk District analyzed the project delivery method against the traditional Design-Bid-Build and Design-Build methods (Figure 6.2.). Ultimately, IDBB provided the greatest likelihood that the project would meet the rigorous BRAC schedule and provided adaptability for addressing the evolving needs of the medical community.
When the Norfolk District developed the project delivery approach, ‘World Class Standards’ was ill-defined and constantly evolving. Through the support and cooperation of several stakeholder agencies, the principles that defined ‘World Class’ for the scope of Fort Belvoir’s project included: “a premier community-focused military hospital, rapidly delivered to meet the needs of deserving beneficiaries, patient-family centered care, highly flexible architectural design, and LEED-Silver certification” (Norfolk District, 2010). A key element of the CMAR project delivery framework was maintaining the owner-designer trusted, fiduciary relationship. The Design-Build delivery method lost this relationship, and thus, limited the owner’s ability to adapt to changing standards.

**Timeline**

The early involvement of the Builders’ Joint Venture enabled the project to enhance the design and pre-construction, early-order materials and services, and begin construction prior to 100% completed design plans. Gilbane and Turner were brought into the project at the 10% design-completion mark, and credited the selection of IDBB as contributing greatly to speed of design, earlier field work, and overall schedule reduction (Schramm, 2011).
Flexibility
Incorporation of the end-user into the project development team was critical for the Norfolk District as the nebulous 'World Class Standards' and 'Evidence-Based Design' criteria brought on significant outside interest and uncertainty. The medical community contributing to the project delivery team (PDT) included: the U.S. Army Health Facilities Planning Agency, the Tri-Care Management Agency, the Joint Task Force National Capital Region/Medical, and the local Dewitt Medical Center Command (as shown in Figure 6.3.). These organizations provided the PDT with the latest requirements and technical integration standards for medical practices and Information Technology (IT) systems (Norfolk District, 2010).

Figure 6.3. Fort Belvoir Community Hospital Project Delivery Team (Norfolk District, 2010).

Risk
The primary risk for CMAR was the lack of sufficient pricing and schedule certainty at the time of initial CMAR selection (10% design in this case). While schedule slippage was not realized, the ‘Iron Triangle’ of cost, scope, and schedule could not be maintained with the accumulation of facility specifications/additions and an unwavering delivery date. The final costs realized for the Fort Belvoir Community Hospital project were over $1.2 billion, from initial estimates below $500 million (which equaled cost-growth in excess of 140%) (Norfolk District, 2010).
Complexity
While the site development and medical facility were complex structures, this aspect of complexity risk pertained to the challenges of project management for a CMAR project. One HDR architect noted that USACE “oversaw, facilitated, and directed the work of these [design-assist] teams, although direct communication between engineer and detailer was encouraged throughout the process” (Muhlenkamp, 2012). However, a Gilbane Company after action review (AAR) cited USACE's “difficulty managing the process” of pre-construction design-assist as a disadvantage of the method. Appropriately, the added managerial effort required for CMAR constituted additional risk on USACE in terms of project oversight (Schramm, 2011).

Collaboration
The opportunities provided by alternative project delivery also created issues for the practitioners, and the experimental use of IDBB certainly provided challenges. The Gilbane AAR noted that USACE was “not familiar-with/comfortable-with collaboration between designer and contractor,” and recommended the creation of an "IDBB Rulebook" for communicating standards for collaboration (Schramm, 2011). Likewise, the USACE Lessons Learned cited several aspects of pre-defining collaboration standards to ensure the PDT resources were most optimally used. One such recommendation was the USACE proposal for “using industry software that has been proven to be highly effective in technical collaboration in the private sector” (Norfolk District, 2010).

Advantages and Disadvantages of CMAR/IDBB for the Fort Belvoir Community Hospital
The CMAR/IDBB structure provided many advantages for the Fort Belvoir Community Hospital which included:

- Fast-tracking capability through early contractor and tradesmen involvement and the early acquisition of cost-variable materials and services.
- Design-Assist improved-upon and sped-up the total project design.
- Design-Assist enabled enhanced collaboration and a better understanding of the design by the contractor, which led to earlier site work.
- Pre-construction and early building collaboration enabled real-time feedback from the contractors to designers (Schramm, 2011).
- Faster overall project delivery in comparison to Design-Bid-Build, which successfully met the BRAC timeline.
• Overall, superior quality from enhanced teamwork and collaboration including a diverse PDT of joint venture designers and builders.

The CMAR/IDBB structure also had several disadvantages, which included:

• Extreme cost-growth over the course of the project from user requests, scope changes, change orders, and design clarifications (Norfolk District, 2010).
• External pressure on construction progress led to an early determination to award the CMAR contract, although the design was not sufficiently advanced. Thus, the team maximized early contractor involvement at the expense of eventual cost increases (Norfolk District, 2010).
• The transition point from cost-mode to firm-fixed price for the CMAR builders was mismanaged in terms of planning, preparation, and contract execution, and provided a challenge for the CMAR contract (Norfolk District, 2010).
• Collaboration and interoperability created challenges given the multiple stakeholders and two Joint Venture arrangements for designers and builders.
• The lack of contractual and regulatory precedents required additional legal and regulatory considerations in the development and negotiation of the contracts.

Applications for USACE

Despite significant cost growth and some frictions in the integrated construction process, the medical center final project was highly reviewed and the recipient of several honors. The Norfolk District leaders were recognized as the 2013 ‘USACE PDT of the Year,’ a considerable accomplishment especially considering the several billion-dollars of BRAC programs executed during that period (Bloodgood, 2014). Also, the application of IDBB enabled the team to accomplish its two largest goals: schedule delivery in September of 2011 (the hospital was operational one month early), and the provision of ‘World Class Standards’ (the hospital was labeled the flagship for new military medical construction and achieved LEED-Gold certification).

As echoed by the contractor and USACE AARs, the Corps has a long way to go in developing standards for the future use of CMAR/IDBB on mega-projects, but a few appropriate applications could include:

• Highly specialized military or inter-agency projects (for example: medical facilities, research centers, military technology facilities, or other unique government projects).
- Very rapid project delivery when fast-tracking is essential.
- Projects where cost growth is acceptable and not a critical concern.
- Collaborative efforts with extensively diverse stakeholder interests and multi-party engagements.
- Novel facility concepts where design and functionality have prominent importance.

Conclusions
The CMAR/IDBB method was effective for delivering the Fort Belvoir Community Hospital on schedule and at a high level of quality. Unfortunately, the CMAR method contributed to huge budget over-runs, many of which were caused by the very early involvement of CMAR consultants, the transition from cost-mode to a fixed-price construction contract, the lack of competitive bidding for construction, and inflated scope adjustments. Nevertheless, the CMAR structure provided an architect-owner fiduciary relationship, fast-tracking ability, early contractor involvement, and enhanced project collaboration, which equipped USACE Project Managers with the required tools to complete the project to BRAC timeline and quality standards. Furthermore, the lessons learned for this project enabled future USACE applications of the delivery method, and advanced the refinement of the CMAR process for USACE. The case study exemplified that CMAR project delivery can be applied to highly technical, schedule-driven USACE projects, and is best-suited for innovative or unique construction requirements.

From March to April of 2009, North Dakota and Minnesota experienced disastrous flooding along the Red River of the North which caused damages in excess of $55 million and the destruction of substantial property (National Weather Service, 2009). Extensive rainfall from the previous autumn season (upwards of 200% greater than usual), added to snow pack, frozen soil, and a record March precipitation event, which culminated in the largest flood on record for the region (in terms of river flow rate), and equated to a 50-year flood event. The Red River of the North establishes the border between North Dakota and Minnesota collecting all flowing waters from the Red River Valley watershed and associated streams and rivers. It flows south-to-north into the Canadian Province of Manitoba, and eventually into the Hudson Bay further to the north.

Straddling the river are the twin cities of Fargo, ND and Moorhead, MN. These cities experienced 16 Red River ‘Major Flood Stages’ since 1900, and half of those occurred in the past 20 years (Boerboom and Dodds, 2017). A 1997 flood disaster shook the region with 11 associated fatalities, over $3.5 billion in damages, and the evacuation of 80,000 citizens (Pioneer Press, 2007). The event prompted the swift regulation of building plans, the construction of protective dikes, the preparation of emergency response coordination, and the establishment of studies to determine a permanent flood risk management solution. In 2001, Fargo received a FEMA Grant to conduct studies and develop project plans to present to the public. Additionally, the U.S. Army Corps of Engineers, with sponsorship from the twin cities, invested several hundred-thousand dollars into dozens of alternative studies to address the infrastructure challenge (Boerboom and Dodds, 2017). The 2009 'Flood of Record' expedited the urgency of establishing a long-term design solution for flood risk management for the region, and in 2011, the Chief of Engineers’ report was concluded.

The Water Resources Reform and Development Act of 2014 authorized a P3 Pilot Program for USACE Civil Works endeavors, and the St. Paul District seized the opportunity. Recognizing that the final expenses for the flood risk management project would greatly exceed the available federal contributions ($850 million authorized), the St. Paul District and Fargo-Moorhead region developed plans to execute the first USACE P3. In the fall of 2017, the project stalled and remained in pre-construction, but with invested public and private stakeholders, the development of a long-term flood management solution rested on future negotiations.
Figure 6.4. 2009 Red River Flood Event (Federal Emergency Management Agency, 2009).

Title: Fargo-Moorhead Area Diversion Project
Location: Red River of the North, near the twin cities of Fargo, ND and Moorhead, MN; within Cass County, ND and Clay County, MN respectively
USACE: St. Paul District, Mississippi Valley Division
Client: Flood Diversion Board of Authority: formed from a joint powers agreement including the cities of Fargo and Moorhead and the counties of Cass and Clay (Board of Authority also includes Committees for Public Outreach, Finance, and Land Management)
P3 Entity: Not selected as of late 2017 (the Flood Diversion Board narrowed the applicants to four partnerships currently developing proposals) (Fargo-Moorhead Area Diversion – Shortlists Four P3 Teams, 2017)
Architects: Not yet selected for P3 entity as of late 2017 (all preliminary design work to-date was executed through USACE, local engineering firms, and consultants)
Contractors: Split delivery plan includes: the USACE-led Southern Embankment – partially awarded to Ames Construction Inc. in December 2016; and the Diversion Channel – P3 entity not yet selected as of late 2017 (Williams, T., 2017)
Finance and Operations: Not selected as of late 2017
Cost: estimated $2.2 billion ($450M federal, $570M from North Dakota, $43M from Minnesota, and $1.1B to be raised locally through increased taxation through 2084) (Fargo-Moorhead Area Diversion – About the Project, 2017)
Schedule: Study and Design (2008-2016, 9 years); Construction (2017-2024, 8 years); Operation (2024-TBD)
Scope: Approximately 11 miles south (upstream) of Fargo-Moorhead, a massive tieback embankment will stretch 12-miles to the east of the Red River to form a blockade limiting the advance of floodwaters. The floodwaters and Red River excess are directed through a Control Structure to a Diversion Channel that stretches 30-miles around the Fargo-Moorhead metro region in a semi-circle direction, and distributes the floodwaters back into the Red River north of the cities. The 1,600-foot wide channel requires the construction of 19 roadway bridges, 4 rail bridges, and multiple river cross-over aqueducts and spill ways (Fargo-Moorhead Area Diversion – About the Project, 2017).

Key Deliverables: Embankment and diversion channel to mitigate Fargo-Moorhead flood risk for a perspective 100-year storm, inlet structures along the channel to reduce flooding in the peripheral communities, protective levees throughout the Fargo-Moorhead metro area and for the municipalities within the ‘staging area,’ protective barriers surrounding key infrastructure found in the ‘staging area,’ and P3 incorporated operations and maintenance for a 30-year period after construction completion.

Description
The Fargo-Moorhead Area Diversion project aims to safeguard the nearly 225,000 people that call the community home, as well as roughly $14 billion in property. The Red River of the North flows directly through the Fargo-Moorhead metro center, and commonly sees river gage readings between 15 and 20 feet of depth. For perspective, the 2009 flood event experienced record peaks for Red River flows and the Fargo gage cited 40.8 feet of depth (Fargo-Moorhead Area Diversion – About the Project, 2017). While some areas of the city are built on higher ground, those increases in river depth cannot be managed by levees alone, and models predict that a 100-yr flood event could reach depths up to 42.5 feet. A 100-yr flood event has the potential to catastrophically damage the metro area and its infrastructure, and thus the need for flood risk mitigation is vital. Addressing the challenge from dozens of alternate directions, the Diversion Channel is determined to have the least impact on existing structures and lands while providing the maximum amount of protection.

The initial undertaking includes the creation of the Southern Embankment and development of the upstream staging area (Figure 6.5.). This engineering task requires the construction of a 12-mile wall approximately 20-25 feet in height (Fargo Moorhead Area Diversion – Frequently Asked Questions, 2017). The Red River, and the nearby tributary Wild Rice River, will have gated control structures to limit the river flow downstream, directing floodwaters toward
the Diversion Channel. Although the floodwaters will primarily be directed through the Diversion Channel and around the metro area, the region to the south will experience more significant flooding due to the presence of the Southern Embankment (see Figure 6.6.). The 'staging area' encompasses nearly 150,000 acres but only impacts approximately 100 residential properties and mostly rural farmlands (Boerboom and Dodds, 2017). Per the Diversion Authority, all
landowners of property needed for the project will receive compensation through federal processes by land-agents (Fargo-Moorhead Area Diversion – Frequently Asked Questions, 2017). Additionally, homes with a projected flood water height of 3-feet during a 100-year storm must be purchased by the Diversion Authority, and those with flood heights of at least 1-foot may be protected through ring-levees. Future management of the staging area, and protection of the properties therein, will be regulated through strict flood-plain management ordinances.

The Diversion Channel affects approximately 1,125 parcels of land in North Dakota as it stretches 30-miles around the Fargo-Moorhead metro region (Fargo-Moorhead Area Diversion – About the Project, 2017). At nearly 1,600 feet wide, the Diversion Channel cross section includes a meandering, low-flow channel at its center (the lowest elevation). Protected prairies flank the low-lying channel and rise-up to meet the raised-elevation maintenance roads that run parallel to the direction of flow. As the Diversion Channel wraps around the metro region, interstates, county roads, and railroads will all pass over the channel on bridges. Additionally,
the major rivers that intersect the Diversion Channel will pass over the channel on raised
aqueducts with spill-over into the Diversion Channel during flooding, and additional minor rivers
will be diverted into the new Diversion Channel. While construction has started on the Southern
Embankment control structures, the design and construction of the Diversion Channel are still in
the conceptual phase, and are pending the selection of the P3 partner.

Elements of P3 Risk for the Fargo-Moorhead Area Diversion Project
Although the P3 portion of the Fargo-Moorhead project has not materialized as of late 2017, the
negotiations between interested stakeholders, law makers, and government agencies are
actively focused on delivering the necessary project using the boost of private investment. As
the project strategy shifted to a Split Delivery Plan, the essence of P3 is still there, but the
USACE role is now concentrated on the Southern Embankment. While still an active participant
in the project planning, the focus of the USACE effort has moved to the design and construction
of the “High Hazard Dam” and associated control structures (Boerboom and Dodds, 2017).
Nevertheless, the executed P3 to this point can be discussed in terms of project risk drivers and
their impact thus far.

Impacts to Schedule
There are two components to schedule where the owner can greatly benefit from the P3. The
first, is the earlier execution of the project given private investment. In many cases, a local or
state government cannot afford to complete a mega-project due to lack of funds and federal
accounting mechanisms. In the case of Fargo-Moorhead, the federal government appropriated
$850 million which would not have sufficed to complete the entire desired project. Private
investment enables the region to secure the infrastructure more quickly, while paying off the
investment over time. Secondly, one of the benefits of executing a P3 project is the ability of a
private P3 partner to fast-track design and construction. Once selected, it is likely this project
will be able to achieve greater schedule efficiency than traditional public projects.

Legal Risk
The legal processes for public project delivery were not yet in-place to support P3s for federal
water infrastructure. Thus, the entire process of executing the Fargo-Moorhead Area Diversion
Project required substantial time and effort to create an environment where a USACE P3 could
be authorized. The Feasibility Study conducted by USACE was initiated in 2008, and completed
and approved in 2011, and the Record of Decision was signed in 2012 (Williams, T., 2017). The
Project Partnership Agreement was finally signed in July of 2016, and the first federal construction contract was awarded in December of 2016. However, in October of 2016, the Minnesota Department of Natural Resources filed a lawsuit alleging that Minnesota permits were required prior to construction. An injunction issued in September of 2017 halted all construction progress until litigation resolution.

**Political Risk**
The Diversion Board of Authority, many of whom are elected officials, represent the constituents of surrounding towns and counties, and the diverse interests therein. The public opinion of the project weighs substantially on its future success, and management of expectations and interests becomes a significantly challenging endeavor. As of late 2017, all active USACE construction was stopped, and the injunction encouraged additional rounds of regional negotiations. The Governors of North Dakota and Minnesota met with the Diversion Board of Authority to conduct a five-part conference to resolve collective concerns (Fargo-Moorhead Area Diversion – Governors’ Task Force, 2017). The regulatory hurdles of the project are far from over, and are representative of the challenges associated with executing P3s in general.

**Financial Risk**
The capital investment for the federal government is significantly reduced from $850M to $450M through the application of the P3 contract. While the private partner finances a portion of the project, they will be repaid via annual allotments from the local municipality sales tax proceeds. Accepting half of the financial burden of this project, the Fargo-Moorhead community approved sales tax increases and an incremental multi-generational repayment plan (Boerboom and Dodds, 2017). One of the greatest benefits of the P3 structure is the transferring of financial risk onto private investors, but it’s also a highly contentious component, and an area that requires further improvement.

**Design and Construction Risk**
Once cleared for execution, the bulk of the design and construction effort will be the sole responsibility of the P3 enterprise. Up to this point, the Corps of Engineers has taken the lead on the technical design of the system under the direction of the Diversion Board of Authority. Once contracted, the P3 entity will furnish the remaining design documents and construction plan, thus alleviating the USACE District of this role.
Operations and Management Risk
The operational and management risks fall entirely on the P3 entity for the first 30 years of the Diversion Channel operation, as per the contractual agreement. While the upfront costs of the project are substantial, they will be repaid annually throughout the project life, and the public owner is relieved from the burden of project operations and maintenance.

Advantages and Disadvantages of P3 for the Fargo-Moorhead Area Diversion Project
The P3 structure promises many potential advantages for the Fargo-Moorhead Area Diversion Project, including:

- Accelerated project delivery and construction timeline.
- Reduced cost to federal tax payers given private investment and long-term regional sales-tax repayment.
- Reduced wait time for infrastructure, thus protecting the region, property, and economies more quickly than traditional methods would achieve.
- Reduced risk exposure over the life of the project, including the reduction of federal risk to non-federal sponsors and private industry.
- Demonstrates applicability and procedures of alternative project delivery and financing for future USACE projects (Thorndike, 2016).

The P3 structure also creates several disadvantages, including the following:

- Ambiguous and ill-defined roles for USACE amongst the non-federal parties, the Diversion Board of Authority, and the private P3 partner (Thorndike, 2016).
- Reduction in federal funding increases the burden on the non-federal parties causing additional imbalance to the federal government’s authority on the project execution.
- Establishment of the project proposal and contract given the various stakeholders and joint powers agreements (Thorndike, 2016).
- Wavering public sentiment on the execution of the project, and some outright displays of protest over the execution of the P3 project.
- The lack of legal and regulatory precedent creates an elongated approval process, and increases the opportunities for lawsuits.
Applications for USACE
The Fargo-Moorhead Area Diversion project offers a unique case study as it represents the seminal effort by USACE to execute a P3. The project provides an appealing opportunity for a P3 as it meets several applicable criteria: an essential infrastructure need for a region, opportunity for revenue generation by willing participants (voter-elected sales tax increases), and capable and interested private partners (four qualified proposals in progress). While the St. Paul District and the Diversion Board of Authority are still in the early phases of the project with many challenges ahead, the P3 project does have federally authorized funding and participation from state and local government leaders. As USACE continues to explore P3 project delivery, there are select uses where private investment makes sense for the Corps of Engineers:

- Revenue generation potential exists through taxes or tariffs tied to a provided service.
- Infrastructure projects that do not span multiple states; or states with differing or non-existent statutes/regulations regarding P3s.
- Regions where public sentiment toward P3s is positive or neutral, and the desire for infrastructure outweighs the cost to the public.
- Civil works projects that are large enough to draw private investment interest and qualified designers/builders, while also enticing as profitable opportunities.

Conclusions
While the potential for P3 project delivery exists for some public infrastructure (roads and highways, water and wastewater treatment, for example) there are other applications where the project delivery strategy is not applicable. Most of the USACE business lines do not provide valid uses for P3 delivery, as private investment is not suitable for federal agency facilities and military installations. Thus, the USACE Civil Works program is responsible for further developing the P3 delivery standards and the way-ahead for federal water infrastructure. The Fargo-Moorhead Area Diversion project provides the furthest-developed example of a USACE-implemented P3, but at its current state, the project does not provide substantial evidence for the benefits of P3. Conversely, the Fargo-Moorhead project has seen significant challenges in financing, technical design, and political approvals. Many of those concerns are the result of the project’s nature, considering the diversion and staging of destructive flood waters. But nevertheless, the project is representative of the difficulties an owner faces when attempting to merge private funding with public infrastructure, and therefore, the applicability of P3 project delivery for the Corps of Engineers demands further refinement from the P3 Pilot Program.
6.3. Integrated Project Delivery: Autodesk Inc. AEC Solutions Division Headquarters

Autodesk Inc., the creators of AutoCAD and other architecture, engineering, and construction (AEC) software, commissioned a $13.3 million interior fill-out project for a new division headquarters near Boston. With an aggressive timeline of 9 months to occupancy, the project emphasized the utilization of BIM software and implemented a pure-IPD project delivery approach. In 2010, the American Institute of Architects (AIA) – California Council assessed six representative case studies of completed IPD projects, including the Autodesk HQ building in Waltham. The Autodesk project was the quintessential application of Integrated Project Delivery, meeting all six fundamental characteristics of IPD as defined by the AIA – California Council: “Early Involvement of Participants, Multi-Party Contract, Shared Risk and Reward, Collaborative Decision Making, Liability Waivers, and Jointly Developed Goals” (Cohen, 2010). This case study evaluates the application of IPD for the Autodesk project, provides advantages and disadvantages for the use of IPD, and proposes take-aways for the implementation of IPD within USACE.

Title: Autodesk Inc. AEC Solutions Division Headquarters
Location: Waltham, MA (16 miles west of Boston, MA)
Owner: Autodesk Inc.
Architect: KlingStubbins
Contractor: Tocci Building Companies
Cost: $13.3 million
Schedule: 9 months
Scope: 55,000 sf interior office fit-out: offices, conference rooms, kitchen, training facilities, and a customer briefing center with Autodesk gallery (Cohen, 2010).
Key Deliverables: Meet the rigid 9-month schedule, stay within budget, achieve a LEED Platinum Commercial Interiors (CI) rating, extensively use Autodesk BIM products, and contractually agree to IPD terms of shared risk and reward (Bendewald and Franta, 2010).

Project Description
Autodesk was founded by John Walker in 1982 with the delivery of AutoCAD. As of 2008, the publicly-held company supplied over 100 different design software products, and had over 9 million licensed users generating $2 billion in annual revenue (Edmondson and Rashid, 2011). Throughout the 2000’s, the company grew quickly with a focus on innovation and the acquisition.
of software companies, many providing complimentary products or services to expand AutoDesk’s AEC portfolio. With the acquisition of Revit Technology, AutoDesk was able to evolve from advanced technical drawings to building information modeling (BIM). With the advent of BIM tools, architects, engineers, contractors, and tradesmen were able to communicate and integrate plans, deconflict overlapping work, and provide owners with 3D visualizations of the completed project. As an innovator and business leader, AutoDesk Inc. looked to their new AEC Headquarters project to serve as an example for construction industry efficiency, waste reduction, and technological collaboration. The Request for Proposal was sent to five selected architects and included the following goals: “practice IPD, use AutoDesk’s BIM tools, and meet very high sustainability objectives.”

The KlingStubbins architect and engineering design firm was one of the selected companies to bid on the AutoDesk project. Teaming with Tocci Building Companies, another early adopter of BIM-enabled projects and lean construction, the two organizations developed a bid proposal with the project schedule and budget in-mind. Once notified that their bid was selected, the companies began the contracting process. The contract negotiations included four unique components: the prohibition of litigation (unless under extreme neglect circumstances); early involvement of key players; collaborative project management from the owner, designer, and builder; and a joint compensation system (Edmonson and Rashid, 2011). After a month of contract negotiations, the IPD team was established and co-located at the architect’s office to continue their develop of the BIM designs. With the integrated approach, the contractor was able to immediately acquire long lead-time products and services. After two months, the project saw one of its few scope changes when the AutoDesk lead wanted a more iconic component to the building’s foyer. Despite minimal time for added work, the proposed plan called for “cutting a three-story atrium” up through the building with a skylight opening at the top (Cohen, 2010). As the architects modeled designs and the contractor developed budget/schedule changes, the BIM 3D visualization was completed in only a week, and AutoDesk approved the change as shown in Figure 6.7. As the design neared completion and the BIM model was ready for execution, the IPD team was relocated to the Tocci offices at the construction site. The completed project cost $13.34 million of the $13.45 million budgeted, and was completed in just under 9 months.
Six Tenets of IPD
Given a brief background of the AutoDesk AEC Solutions Division HQ project, this section focuses on the specific applications of IPD and how the AutoDesk team addressed those components. The AIA – California Council's defining IPD characteristics are used as the framework for understanding IPD implementation (Cohen, 2010).

1) Early Involvement of Key Participants
The AutoDesk RFP for the project deliberately specified the use of IPD and the requirement for an IPD contractual obligation between the owner, architect, and contractor. Thus, a legitimate bid submission required the input of an architect and builder. Once selected, the contractor co-located with the designer to further provide consulting services. During the contract negotiation period, the designer and contractor further developed the proposal, schedule, and delivery plan (Edmonson and Rashid, 2011). Early involvement also enabled fast-tracking of the project and the procurement of materials, services, and sub-contractor commitments as early as possible.
2) Multi-Party Contract
The IPD contract addressed: no litigation, shared risk and reward, joint PM responsibility, and early involvement. In addition to the owner, architect, and builder, three subcontractor companies were included in the IPD contract: Electrical, Dry Wall, and M/P/FP (Mechanical, Plumbing, and Fire Protection). The contract clearly delineated the responsibilities of each party, and required that all parties work at-cost, sharing in the incentive program (Cohen, 2010).

3) Shared Risk/Reward
The contract specified the compensation structure, and distributed the risk and reward across all signees as follows: all parties compensated for direct costs (labor, materials, etc.); additional costs permitted (travel, overhead, etc.); a contingency fund to address overages or minor scope change (funds earmarked for project changes and if not used – 40% retumed to owner, 60% to IPD team); and an Incentive Compensation Layer (ICL) – essentially, the available profits for each firm (if project overages surpass contingency fund, the ICL is liable, but otherwise the ICL is distributed accordingly and tied to the success of the project). ICL distribution was based on quantitative goal establishment (project schedule, project costs, project LEED points), and a qualitative review based on a third-party arbitrator.

4) Collaborative Decision Making
Project work was executed with three levels of leadership: the Project Implementation Team – dealt with daily work and often rotated in-and-out of the team depending on work required; the Project Management Team (PMT) – managers representing the owner, architect, and builder, these professionals made decisions on a consensus basis and generally executed most of the project leadership; the Senior Management Team – was represented by the principals for each organization and required a 2/3 approval if the PMT could not reach unanimous decision.

5) Liability Waivers Among Key Participants
IPD contract signatories “waived all claims against each other except those arising from fraud, willful misconduct, or gross negligence” (AIA California Council, 2010). Parties maintained individual insurance policies with no subrogation against each other. Conflicts not resolved through the Senior Management Team were directed to mediation or arbitration if required (Cohen, 2010).
6) Jointly Developed/Validated Targets

The contract’s compensation plan relied on the team’s ability to meet non-objective criteria of costs, schedule, and LEED points. For the quality assessment, a third-party evaluator assessed the project in comparison to three previously agreed-upon ‘like projects’ (Cohen, 2010).

Advantages and Disadvantages of IPD for the AutoDesk Project

The BIM-enabled IPD structure provided many advantages for the AutoDesk project, including:

- Fast-tracking capability through early contractor and tradesmen involvement and the early acquisition of cost-variable materials and services.
- Ability of the designer and builder to reallocate project funds as needed and to pool resources (i.e. a joint rental agreement for lifts to serve all trades) (Cohen, 2010).
- Collaborative effort on BIM enabled design-to-fabrication for the facility’s custom wood paneling. Additionally, subcontractors directly inputted their pre-fabricated equipment into the BIM model for conflict reduction (i.e. HVAC systems, plumbing, electrical, fire protection, etc.) (Bendewald and Franta, 2010).
- Elimination of shop drawings through the application of BIM design and the interaction between designers and builders (also leading to reduced RFIs and less rework).
- Completed project models were available for facilities operators after construction completion.
- As opposed to project-tracking with a Gannt chart, the job-site displayed several screens with 3D models highlighting the work to be completed and associated construction details (Bendewald and Franta, 2010).
- The designer and builder were contractually obligated toward the project, and did not benefit by shifting risk toward the other party, thus, generating greater cohesion and motivation to jointly achieve the Incentive Pay (Bendewald and Franta, 2010).

The IPD structure also had several disadvantages, which included:

- The designer, builder, and subcontractor had interoperability issues with the collaborative software. Several of the tradesmen used specialized programs to develop their systems, and merging or uploading data was challenging (Bendewald and Franta, 2010).
Signing the IPD contract exposed all parties to risks considered abnormal compared to common industry standards, and buy-in from company executives was difficult for some parties.

A lack of contractual precedent required additional legal and regulatory considerations in the negotiation of the contract.

Excessively large data files hindered remote access to the BIM models, which also served as the primary construction documents (Cohen, 2010).

The Contingency Fund, an aspect of the budgeted project, was established to cover scope adjustments and project over-runs, but not scope add-ons. It was also incorporated into the project incentive pool for the designer and builder (if a balance remained after construction completion). Thus, using the Contingency Fund as an additional financial incentive worked contrary to the IPD team’s goal of delivering the best project at the targeted schedule (Cohen, 2010). Applying the Contingency Fund toward scope adjustments presented a conflict of interest for the IPD team that was concerned with preserving potential profits.

Applications for USACE
The AutoDesk Inc. AEC Solutions Division HQ project provided a seemingly flawless execution of IPD delivered by competent professionals for a knowledgeable owner. The project was considered a “triple-win” as “design and construction costs ended up below target (benefitting both the design-build team and owner), designer and contractor profits exceeded targets, and the building achieved LEED-CI Platinum and all other goals” (Bendewald and Franta, 2010).

Not detracting from the success of the project, the experience level with BIM and IPD by the owner, designer, and builder greatly contributed to the project’s success. Many organizations are unfamiliar with the IPD delivery process, and most public agencies do not likely have the technological or contractual experience to perform IPD seamlessly. While executing a pure-IPD project delivery may not be an impending option for USACE, there are several components of IPD that can be emulated for the betterment of project management:

- Development of a highly collaborative project team with contractor early involvement.
- Contractual incentives for the collective team based on budget, schedule, and quality goals that are jointly developed.
- A multi-party approach ensuring designer, contractor, and key trades are collocated, invested in the project, and collaborating with Building Information Modeling software.
- Collective decision making with owner, designer, and builder input.

**Conclusions**

Pure-IPD project delivery is not feasible for the Corps of Engineers as liability waivers and competitive bidding are generally unanimous requirements for federal infrastructure projects. However, IPD philosophies could be integrated into existing regulations, including: early involvement of participants, shared risk and reward, collaborative decision making, and jointly developed goals. To enable these innovative components would require significant development by USACE contracting officials and specific, unique project needs. The ideal application of IPD for USACE projects would include an element of design or construction specialization, a need for enhanced collaborative technological modeling, a requirement for fast-tracking, or the early involvement of the builder. IPD as a delivery method is not practicable for USACE, but the tenets of IPD, and the lessons learned from the AutoDesk Inc. case study, offer insights for Project Managers interested in implementing innovative project methods.
Chapter 7. Alternative Project Delivery within USACE

7.1. Conclusions and Recommendations

This thesis initiates with an overview of the status of national infrastructure and the construction industry. Next, the role of USACE, a relevant history, applicable regulations, task organization, and an overview of key stakeholders is provided for further context. With a firm understanding of the current state, the thesis reviews the USACE Project Management Business Process to discuss the prescribed method for project delivery within the Corps. After, the report notes several observations of project delivery ‘in-practice,’ project cost and growth statistics, and a real-world stakeholder analysis. Chapter 5 provides a literature review of currently applied project delivery methods, as well as three alternative methods: Construction Management at Risk, Public Private Partnerships, and Integrated Project Delivery. Reviewing the project delivery options, Chapter 5 concludes with a matrix highlighting the applicable project drivers for each delivery method. Lastly, the report offers three case studies exemplifying the alternative project delivery methods discussed, noting key lessons learned, implementation strategies, and benefits/disadvantages of the methods.

Project delivery for the Corps of Engineers is big business, with project appropriations in the tens of billions of dollars each year. While a USACE District has direct control over their individual projects, politicians and senior military echelons influence the project pipeline, pass regulations, and can intervene on troubled or delayed projects or programs. As covered in the stakeholder value network, the PMBP process is influenced by a host of external organizations and senior leaders. Therefore, to implement alternative project delivery strategies, a synchronized effort is required by lawmakers and USACE leaders alike. Alternative project delivery methods provide Project Managers and District Commanders with greater flexibility in developing the project acquisition strategy. As shown in the first two case studies, alternative methods can enable collaboration, construction expediting, and financing options that were previously unavailable to USACE, and the Integrated Project Delivery case provides an example of harnessing technology-enabled, collaborative teamwork. In summary, Figure 7.1. provides the recommended alternative project delivery methods that are applicable for each USACE Line of Effort, with the associated project drivers for implementation.
<table>
<thead>
<tr>
<th>USACE Project Lines of Effort</th>
<th>Construction Manager at Risk (CMAR) &quot;CM/GC&quot; &quot;CM@R&quot;</th>
<th>Public Private Partnership (P3) &quot;Build Operate Transfer&quot; &quot;Long-Term Leasing&quot;</th>
<th>Integrated Project Delivery (IPD) &quot;Near-IPD&quot; &quot;IPD-ish&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Works</td>
<td>-Fast-Track Projects -Early Contractor Involvement</td>
<td>-Revenue Generation Opportunities -Owner Need to Forgo Operations/Maintenance -Qualified/Interested Private Partners</td>
<td>Not Recommended (Cost Effectiveness)</td>
</tr>
<tr>
<td>International Support</td>
<td>-Fast-Track Projects -Early Contractor Involvement -Maintain Owner-Designer Relationship</td>
<td>Not Recommended (Not Applicable for Private Investment)</td>
<td>Not Recommended (Contractual Complexity)</td>
</tr>
<tr>
<td>Environmental Projects</td>
<td>-Early Contractor Involvement</td>
<td>Not Recommended (No Likely Revenue Generation)</td>
<td>Not Recommended (Duration and Cost Effectiveness)</td>
</tr>
<tr>
<td>Contingency Operations</td>
<td>-Fast-Track Projects -Early Contractor Involvement</td>
<td>Not Recommended (Not Applicable for Private Investment)</td>
<td>Not Recommended (Contractual Complexity)</td>
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Figure 7.1. USACE Project Lines of Effort & Project Delivery Methods Matrix
7.2. USACE Lines of Effort and Alternative Project Delivery Methods

As highlighted in Figure 7.1, alternative project delivery methods are feasible and recommended for select USACE business programs. Although P3s are proven in several public sectors, their use within USACE would be limited to Civil Work projects where they are still untested. The Fargo-Moorhead Flood Risk Management project suggests that while this delivery method may have future potential, the application should be limited to very few pilot programs until the process is further refined. IPD provides several valuable insights into collaborative teams and the integrated use of software, but for some business lines, the associated costs and collaboration resources are likely not worth the value-added. Lastly, CMAR is both prevalent in the private sector, and intermittently used within the Corps, and thus, represents the alternative method most suitable for further USACE implementation at this time. As shown in the Fort Belvoir Community Hospital, CMAR can deliver projects quickly and at an enhanced quality, but additional oversight is required to track and limit cost-growth opportunities.

The flexibility of PMBP project delivery options should match the vast diversity of USACE’s missions. With national infrastructure and the construction industry facing substantial struggles, public leaders should invest time and resources into “engineering solutions for our nation’s toughest challenges.” Considering that no single project delivery method will meet all the nation’s infrastructure needs, the U.S. Army Corps of Engineers can benefit from developing their regulations and procedures for adapting alternative project delivery methods for public projects.
Bibliography


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Appendix A. Task Organization and Structure Supplement

Department of Defense

As with many federal agencies of the U.S. government, the general public is often unaware of the agency's purpose or place within the national government. The United States Army Corps of Engineers is a federal agency under the Department of Defense and the Department of the Army. The Department of Defense is led by the Secretary of Defense and is composed of the Joint Chiefs of Staff, Departments of the Army, Navy, and Air Force, and the several Defense Agencies and Field Activities as shown in Figure A.1.

DoD Organizational Structure

Figure A.1. DoD Organizational Structure (Deputy Chief Management Office, 2017)
Department of the Army

The Department of the Army structure includes the main Army Commands (U.S. Army Forces Command, Training and Doctrine Command, and Materiel Command), the Army Service Component Commands, and Direct Reporting Units. USACE is designated a Direct Reporting Unit by the Secretary of the Army as shown in Figure A.2. The Chief of Engineers is the Army’s senior engineer expert, and serves as a member of the Army Staff, advising the Chief of Staff of the U.S. Army. The Chief of Engineers also works with the Secretary of the Army’s staff, including the Assistant Secretary of the Army for Civil Works as highlighted in Figure A.3.

Figure A.2. U.S. Army Organizational Structure (U.S. Army – Organization, 2017)
Figure A.3. HQ, Department of the Army (U.S. Army – Under Secretary of the Army, 2017)
U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers is headquartered in Washington D.C. and is comprised of 9 Divisions with 41 Districts. USACE Headquarters also contains support and administrative centers as well as several DoD and Engineering research facilities. Reporting directly to the USACE HQ are two U.S. Army Reserve Theater Engineering Command HQs and the 249th Prime Power Battalion, an active-duty power generation battalion with responsibilities including crisis response and contingency operation support for military units and federal relief organizations. Located in the nation's capital, the USACE HQ works with federal lawmakers and adjacent government agencies to develop national infrastructure priorities and deliver programs along their lines of business. The Chief of Engineers is aided by a staff which includes support offices as well as sections for each business program. USACE Programs are headed by Deputy Commanding Generals or Senior Executive Service civilian Directors. Programs include Civil and Emergency Operations, Military and Interagency/ International Operations, Army Geospatial, and Engineer Research and Development. As shown in Figure A.4., the USACE Divisions are representative of the Corps HQ's maneuver units, each with their own respective areas of operation, and a further decomposition of the North Atlantic Division follows.
U.S. Army Corps of Engineers (USACE) Headquarters

Figure A.4. USACE Organizational Structure (USACE 101, 2016)
USACE – North Atlantic Division

The USACE Divisions are spread geographically across the U.S. The North Atlantic Division (NAD) operates along the nation’s northeast coast from Maine to Virginia and covers portions of 14 states, and includes over 60 million citizens (North Atlantic Division, 2017). Each Division similarly includes offices for the various support and administration functions to run business operations, interact with USACE HQ, and distribute policy and direction to the District offices. Support functions generally report to the Deputy Division Commander within the executive office. Additionally, regional business directorates and program directorates address the Division’s lines of business and major initiatives (Figure A.5.). Within the NAD, the Sandy Coastal Management Division address coastal rehabilitation projects throughout the region, regardless of state or District affiliation. And as such, NAD is designated as the National Planning Center of Expertise for Coastal Storm Risk Mitigation (North Atlantic Division, 2017). Furthermore, the Division leads six District offices located in Baltimore, MD; New York, NY; Concord, MA; Norfolk, VA; Philadelphia, PA; and Wiesbaden, Germany. The NAD region includes 50 military installations, and has spent over $7 billion in BRAC base realignment and closure projects. Additionally, the region encompasses some of the nation’s largest port cities, navigation channels, dams, and levee systems. The Division headquarters provides guidance and support to the District offices and levels available resources and expertise throughout the region.
Figure A.5. North Atlantic Division Organizational Structure (North Atlantic Division, 2017)
USACE – New England District
As with the Divisions, the 41 USACE Districts are spread across the U.S. and abroad and support the various lines of effort in their designated territories. USACE Districts are comprised of advisory and administrative offices and technical offices. Many Districts operate in the matrix organization format, where employees are assigned to a functional department, but are reassigned on an as-needed basis to support projects. The Districts operate independently, but they also collaborate throughout USACE for resource availability, and coordinate lessons-learned and design specifications through designated centers of expertise and centers of standardization. An Army Engineer Colonel or Lieutenant Colonel commands each District with a military officer deputy and a senior civilian Deputy District Engineer. A District may have several hundred DoD civilian employees at multiple offices throughout their designated region, but there will only be a handful of active-duty Army Engineers at each District. USACE District employees cover a wide range of technical expertise, administrative skills, and general organizational requirements providing a full range of professional services as indicated in the structural organization shown in Figure A.6. The New England District covers portions of 6 states, over 6,000 miles of coastline, 171 Federal Harbors, 2 active duty bases, and multiple other military facilities (New England District, 2017).
Appendix B. PMBP Systems Architecture Supplement

The Project Management Business Process is shown in Figure 3.1. as depicted by the USACE PMBP Manual (2009).

Decomposition
The PMBP shown in Figure 3.1. represents the level 1 functional decomposition of the Project Life-Cycle. The USACE Project Life-Cycle (level 0) is a four-phase process for executing projects: Project Initiation, Project Planning, Project Execution & Control, and Project Close-out (PMBP Brochure, 2009). Decomposing the process down to understand the inner-workings-of and interactions-between each phase, the PMBP provides 22 discrete activities that must be executed. This level of decomposition provides a reasonably understandable model for how USACE approaches the project delivery process. However, delving into each discrete activity, further tasks and approvals abound. One of the first activities for project initiation involves the acceptance procedures for new work. This activity addresses the required steps for processing new work requests from both existing and new clients, establishing the authority and procedures for accepting the project, and the assignment of new work to project managers (PMBP Manual, 2009). As shown in Figure B.1., this individual activity further decomposes into a flowchart of tasks and decisions for execution by multiple USACE parties. Reducing the complexity of the entire project delivery process, the level 1 decomposition of the PMBP provides a sufficient explanation for project delivery for the purposes of this research.
Figure B.1. Work Acceptance – Activity Decomposition (PMBP Manual, 2009)
Architecture Representation Tools

In the mid 1990’s, Object Process Methodology (OPM) was developed by Processor Dov Dori to unify the “object- and process-oriented paradigms for describing systems in a single methodology” (Crawley et al., 2016). Furthermore, “understanding natural, artificial, and social systems requires a well-founded, yet intuitive methodology that is capable of modeling these complexities in a coherent, straightforward manner” (Dori, 2002). The method relies upon the mapping of form and function, and the relationships therein. A function is represented by a process and the operand that the process affects. Processes are depicted in the model as oval shapes and Figure B.2. shows a simplified sequence of the processes that replicate the PMBP.

Operands are represented within the system as rectangles and can signify the people, decisions, resources, or things that the process affects. Operands are often represented as value-related states awaiting change by the application of the process. The process is also acted upon by instrument objects (rectangles) which can signify an influencing agent, person, or item that effects the process (Crawley et al., 2016). The OPM depiction of the PMBP Level I Processes, Operands, and Instruments is shown in Figure B.3.

The application of Model-Based Systems Engineering in developing system architectures could provide USACE with potential solutions for streamlining processes and promoting flexibility. As discussed by de Weck et al. in Systems Engineering, Model-Based System Engineering (MBSE) refers to “a formal ‘language’ that can be used to describe functions in a way that makes them generally understandable across disciplines while still being precise in its semantics and representations” (de Weck et al., 2016). OPM meets this criterion and “allows systems analysts and engineers to keep system models in a single, unified form that facilitates model evolution, maintenance, and team communications.” While the PMBP Brochure and Manual are succinct and clearly distributed throughout the Corps of Engineers, the process is not easily modified or updated to reflect changes in policy. Thus, evolving the PMBP into a model-based system could promote greater flexibility and the progression of project delivery processes.
Figure B.2: OPM Depiction of the PMBP Level 1 Processes
Figure B.3. OPM Depiction of the PMBP Level 1 Processes, Operands, and Instruments