

Chapter 1

Introduction to Megaprojects and the Big Dig

The difficult is what takes a little time; the impossible is what takes a little longer.

—Fridtjof Nansen, Nobel Peace Prize Winner, 1922

INTRODUCTION

A veritable research and development laboratory of engineering and construction, the Central Artery/Tunnel Project, famously known as the Big Dig, was the largest infrastructure project ever undertaken in the United States and the largest inner-city construction project in the world. Its degree of difficulty was far greater than that of the other megaprojects of the twentieth century, the Panama Canal, the Hoover Dam, and the English Channel Tunnel. Those projects were constructed in “greenfield” sites. There was nothing there. The Big Dig, however, was constructed in the heart of a major, operating city. In addition, the proposed roadways were to be built off of the Colonial shoreline. That meant they would be built not on consolidated soil but on filled land, which possessed undetermined strength characteristics. Due to the proximity of the harbor, the water table throughout this unconsolidated soil was between 5 and 8 feet below the level of the streets. The deepest Big Dig tunnel would have a roadway surface 120 feet below the streets.

The Big Dig turned out to be quite a dichotomy. Challenges that had never before been faced were overcome not only in the design phase but also during construction, and on a daily basis. Technologically, the Big Dig is a resounding success, a marvel of ingenuity, engineering, design, and construction. It did resolve the age-old vehicular gridlock problem in the City

of Boston. However, the road to its completion was paved with extraordinary challenges in its execution.

There is now an unparalleled example of what works and what doesn't work on megaprojects. Each chapter in this book offers a view of the Big Dig from the inside out and attempts to provide a perspective heretofore unavailable. The goal of this book is to convey an understanding of the systemic difficulties in managing large-scale projects and the need to develop better solutions for implementation of these projects, including controlling costs, schedule, scope, quality, and risk. The literature is filled with academic analysis and recommended practices, but, despite the complexity of megaprojects, there is scarce examination of the numerous processes and procedures that govern these projects and the knowledge and skills needed for managing large-scale projects around the world.

The objective of this chapter is for readers to learn the benefits of studying megaprojects, as well as to explore typical characteristics of megaprojects and how projects like the Big Dig are conceived and developed. This chapter provides a brief overview of the characteristics of megaprojects generally and the unique characteristics of a megaproject built through an inner-city as well as the impact and benefits of this monumental endeavor for future project managers. While the primary goal of this chapter is to set forth a framework for understanding the importance and goals of megaprojects, it also analyzes what makes megaprojects unique and worthy of future analysis and research.

WHY STUDY MEGAPROJECTS?

In light of the magnitude and technological complexity of these projects—to say nothing of their intriguing historical and political stories—it is surprising that more has not been written about the phenomenon of megaprojects.

—Haynes 2002

Megaprojects exhibit many interesting and unique characteristics, and many reasons have been advanced for studying megaprojects including understanding how projects create value (Esty 2004) and the concepts and strategies for success (Merrow 2011). There are additional compelling reasons to study megaprojects; a few of the most important are highlighted as follows.

1. Delivery of Lessons from Practice

We cannot undo the past, but we are bound to pass it in review in order to draw from it such lessons as may be applicable to the future . . .

—Sir Winston Churchill

One of the primary reasons for project management research is the development of a body of lessons learned that can be applied to future projects across industries and continents. The greatest teacher is experience, as evidenced in this popular quote from Will Rogers: “Good judgment comes from experience and a lot of that comes from bad judgment.” The many lessons from the Big Dig and other megaprojects must be shared so that all projects can benefit from this experience, both the good and the bad.

In the National Academies’ 2003 report *Completing the “Big Dig”: Managing the Final Stages of Boston’s Central Artery/Tunnel Project* (Board 2003), the committee that reviewed the project management practices employed on the Boston Central Artery/Tunnel (the Big Dig) Project recommended that other megaprojects “could benefit from the lessons learned from the Big Dig—the causes of the many problems . . . as well as the solutions developed by the management team, design engineers, and construction contractors. Participants in these new projects will need to learn how to develop realistic expectations and manage efforts to achieve them.”

During the past decade, megaprojects have had an enormous impact on the global economy and the advancement of transition and developing countries. Research on megaprojects tends to focus on their failures, in terms of cost overruns, delays, and endemic stakeholder conflicts. However, there are also great benefits that are associated with project development and implementation processes that are rarely discussed. This book attempts to focus on both the lessons that are learned when things go wrong, but also the lessons to be gleaned from success, so that they may be systemically pursued.

2. Advancement of Knowledge and Innovation

Institutional learning is proposed as a process through which adaptations can be made to accommodate shortcomings in the prevailing institutional environment (Hall et al., 2001); (Greiman and Rwabizambuga 2009). The nature of megaprojects brings together significant tacit knowledge that is embedded within particular groups in the project (Bresnen 2003). In project-based activities, the flows of personnel, material, and information as social processes are important in the diffusion and transfer of technology and knowledge. Social processes play a great role in the transfer of knowledge and learning. Large projects demonstrate the relationship between knowledge, technology, and organization. This interrelationship emphasizes the importance of structuring the project right from the outset to maximize the flow of knowledge in and out of the project to the benefit of the broader organizational goals.

Advancement of knowledge and innovation at the Big Dig was at the heart of its mission. As noted by the U.S. Federal Highway Administration (FHWA), “[w]hile some aspects of the Central Artery/Tunnel Project (CA/T) in Boston, . . . have been controversial, this monumental undertaking has been responsible for improving the state-of-the-practice in transportation design

and construction” (FHWA 2001). This knowledge includes innovations in managerial, operational, and technological tools and processes. Throughout this book many of these innovations and advancements are highlighted and are used to emphasize the importance of studying megaprojects to gain insights into methodologies and tools for improved practices in future projects. Sharing knowledge is not just a domestic goal but a worldwide strategy led by multinational development banks and country- and region-based knowledge-sharing alliances.

3. Projects as an Engine for Economic Development

Large-scale infrastructure has long been an essential factor in economic development. The U.S. Department of Transportation (USDOT), has recognized that “in rebuilding our roads, bridges, transit systems, and airports, we can spur the creation and growth of small businesses, America’s economic engine” (USDOT 2011). In 2010, The U.S. Department of the Treasury issued *An Economic Analysis of Infrastructure Investments*, which described the merits of direct private investment in infrastructure as follows:

Many studies have found evidence of large private sector productivity gains from public infrastructure investments, in many cases with higher returns than private capital investment. Research has shown that well designed infrastructure investments can raise economic growth, productivity, and land values, while also providing significant positive spillovers to areas such as economic development, energy efficiency, public health and manufacturing.

(Treasury 2010)

Moreover, the Congressional Budget Office has determined that additional investment in infrastructure is among the most effective policy options for raising output and employment (CBO 2010). These positive benefits are a major reason why the lessons from megaprojects are so important in identifying greater opportunities for building efficiencies into our transportation and infrastructure systems and building national communities that can enhance global competitiveness.

4. Global Expansion and Improvement of Societal Benefits

Development projects have had a long history of improving societal benefits including environmental sustainability, quality of life, infrastructure development, and economic viability; however, there is a long way to go, considering that more than half the world—over 3 billion people—live on less than \$2.50 a day (Chen and Martin 2008). In some countries, projects are the only way to deliver sustainable development; thus, understanding how

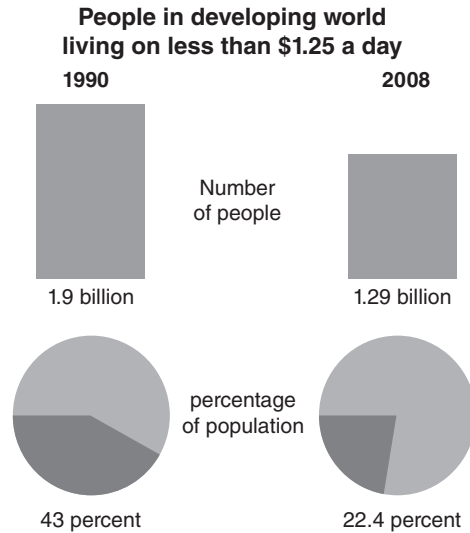


Figure 1.1 Poverty Picture in the Developing World 1990–2008

Source: World Bank: Poverty and Equity Data Portal.

they can be used to greater effect is a key to solving major global problems including poverty alleviation, food security, global health, and the general welfare of local citizens. Figure 1.1 shows the poverty levels in the developing world in 1990 versus 2008. According to the World Bank, the focus on poverty alleviation has reduced by almost half, the percentage of people living on less than a \$1.25 a day (WB 2012; 2011).

As of 2011, an estimated 880 million people in the world live without safe water, 1.4 billion lack electricity, 2.5 billion lack sanitation, and more than 1 billion lack access to telephone services. Total demand for infrastructure investment and maintenance from developing countries is estimated at more than \$900 billion a year, with the greatest needs in Africa and Asia (WB 2011). Increasingly, the Bank Group is linking developing countries so they can share knowledge gained from their experiences. As a group, the bank continues to focus on infrastructure—its largest investment sector—as well as efforts to connect investment to private-sector financing, which includes supporting public-private partnerships. Figure 1.2 shows 53 percent of the lending by sector in Africa dedicated to infrastructure development in Agriculture and Forestry, Energy and Mining, Industry and Trade, Transportation and Water, Sanitation, and Food Protection.

The importance of infrastructure development is further emphasized by the World Bank's partnership with the Government of Singapore, in launching the first Infrastructure Finance Center of Excellence to provide customized services to governments in developed and developing countries as they develop mechanisms to finance infrastructure, including with more private capital.

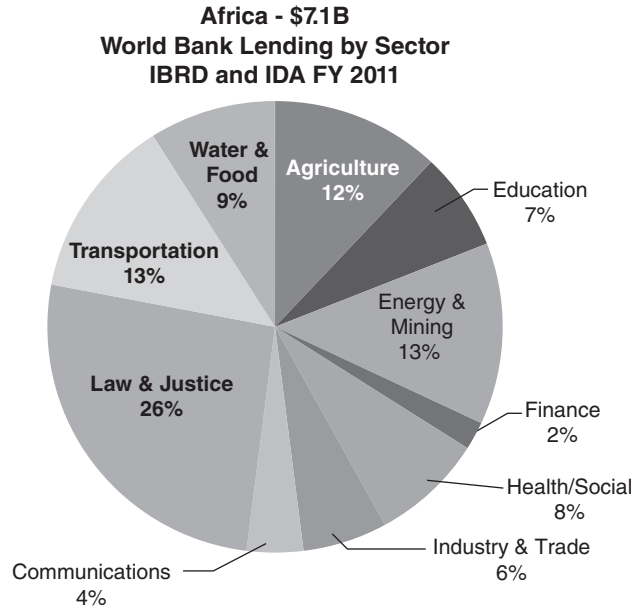


Figure 1.2 World Bank Lending by Sector (Africa) FY 2011
Source: World Bank: Annual Report 2011: The Year in Review: Africa.

5. Fulfilling the Growing Need for Major Investment in Transportation and Energy

Our global society now connects us in ways that we could never have imagined. Seven billion humans now have the opportunity to interact with each other and share knowledge and experience, and our technology enables us to pursue innovative pathways and incredible challenges. Major investments in capital-intensive projects are needed for projects around the globe to build pipelines for the supply of natural gas, to build alternative energy resources such as wind farms, to relieve urban traffic congestion, and to rebuild and modernize bridges, tunnels, and highways as they reach the end of their original design life. The growth in infrastructure investment funds is expected to continue both domestically and globally with billions available in equity to invest in projects that can produce a reliable revenue stream through tolls, tunnels, and cloud-based computer services. The World Bank reports that financing for infrastructure remains its core business, accounting for 46 percent of total assistance in 2011 (WB 2011).

6. Improving Transparency and Oversight

Another important reason to study megaprojects is to learn from the politics of large-scale investment to make sure that, through transparency and public scrutiny, better oversight of these projects is secured.

Megaprojects generate a tremendous amount of scrutiny and public concern. In 2009, the U.S. Department of Transportation (USDOT) Office of Inspector General (OIG) reported 278 indictments and 235 convictions, 191 years of jail time for offenders, and more than \$737 million in fines based on OIG investigations related to highway, transit, and airport infrastructure projects contract and grant fraud (Barnet and Russell 2009).

Senator Fred Thompson's report, *Government at the Brink* (2001), highlights the impact on the public: "These management problems exact a terrible toll on public trust and confidence in the Federal Government. A degree of public skepticism toward our government is a healthy thing. Rampant cynicism is not." He concluded that the combined effect of this cynicism and indifference creates a vicious cycle: "Our leaders can't really be effective if the public feels it can't trust them" (Thompson 2001).

To enhance transparency and streamline government operations, on June 13, 2011, the president used an Executive Order to establish the Governmental Accountability and Transparency Board (GATB) to provide strategic direction for enhancing the transparency of federal spending and advance efforts to detect and remediate fraud, waste, and abuse in federal programs (GATB 2011). In December 2011, the GATB issued a Report and Recommendations to the president recommending the following three actions: (1) the government should adopt a cohesive, centralized accountability framework to track and oversee spending; (2) the government must consolidate and streamline into a single automated electronic collection system that uses a limited but well-defined set of data elements to promote consistent reporting and data standardization; and (3) the government should migrate to a universal, standardized identification system of all federal awards.

These actions are quite common in reference to public projects, and they reflect the vital need to preserve the public's trust. We cannot preserve trust if we do not understand the reality of the complex and difficult-to-understand set of public dynamics (Capka 2004). All projects, whether funded publicly or privately, raise concerns of trust for the simple reason that all projects deliver services, products, or both to the ultimate consumer, the public citizen.

The challenges faced by every project, whether it is a mission to the moon, a nuclear power plant, product development, or a race in cyberspace, involve building trust with all stakeholders. If we fail to meet stakeholder expectations we have impacted our chances for success. Each chapter of this book builds upon the importance of public trust and the approaches and methods for succeeding in projects regardless of the size, complexity or adversity faced by the project promoters.

PROJECTS, PROGRAMS, AND PORTFOLIOS

A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Fifth Edition is a global standard from the Project Management Institute (PMI) that defines project management as "[the] application of knowledge,

skills and techniques to project activities in order to meet the project requirements.” The *PMBOK® Guide* represents what is recognized as common practice in managing projects. Project managers should be skilled at adapting their management methods for the unique qualities of each project. As you will learn throughout this book, in the context of a megaproject, no one size fits all. The project management approach in large scale projects has to take into consideration all of the unique characteristics of megaprojects and will require the use of project standards (*PMBOK® Guide*), program standards (PMI Program Standard 2013) and other methodologies such as agile project management, improvisation, systems engineering and configuration management described in this book. These approaches are often managed concurrently and recognizing these various approaches for enhancing project management success, and when and how to apply each, is critical to effective management of large scale projects.

In the project management literature and in practice, the terms *project*, *program*, and *portfolio* are used interchangeably and can create confusion as to the real meaning of the terms (*PMBOK® Guide* 2013). Although these terms are related, they are not the same. Portfolios, programs and projects are aligned with or driven by organizational strategies (*PMBOK® Guide* 2013). PMI provides standards for managing projects, programs and portfolios and understanding the interfaces between these standards is critical to ensure successful organizational strategies.

The *PMBOK® Guide* describes a “program” as a group of projects managed in a coordinated way to obtain benefits not available from managing them individually, while a “project” is defined as a temporary endeavor undertaken to create a unique product, service or result. A program can also be a larger project that has been broken down into smaller projects. The integrative nature of program management processes involves coordinating the processes for each of the projects or programs, individually and also as a whole system (PMI Program Standard 2013). In this book and in practice we refer to the Big Dig as a project, even though it essentially contains elements of both projects and programs. The interface between PMI’s *PMBOK® Guide* and PMI’s Program Management Standard (2013) is particularly relevant to the Big Dig as each would apply to different elements of the project. For example, on the Big Dig, the multiple interrelated projects for design and construction were managed in a coordinated way as a program; however, within that program were the following individual projects:

- Complete 2 miles of underground highway within the city.
- Build a tunnel to connect the city with an airport.
- Develop a landfill to address environmental requirements.
- Construct an interchange to connect local roadways with an inner-state highway system.

To manage multiple projects, the concept of a *program management office* (PMO) has been established in the project management field. A PMO is defined by PMI as a management structure that standardizes the program-related

governance processes and facilitates the sharing of resources, methodologies, tools and techniques (PMI Program Standard 2013). Program managers coordinate efforts between projects but typically do not directly manage the individual components. Researchers recommend that PMOs should be used only when they add value to the organization (Kendall and Rollins 2003)—that is, when a cost-benefit analysis reflects that there are more advantages to managing multiple projects under one centralized program rather than separately.

In many multinational companies and large organizations, projects and programs are grouped together under a *portfolio*. PMI has established its own Portfolio Management Standard and defines a portfolio as “a collection of components that are grouped together to facilitate the effective management of that work so as to meet strategic business objectives” (*PMBOK® Guide* 2013). Unlike a program, the projects or programs in a portfolio may not be related or interdependent. Portfolios are usually managed at the highest levels of an organization, and the portfolio manager is charged with managing the portfolios based on specific goals. The major goal of portfolio management is to align the portfolio to the strategic objectives of the company. The portfolio provides an overview of the organization’s goals, mission, and strategic objectives. Most large companies and organizations such as NASA, Raytheon, Microsoft, Google, and IBM employ portfolio managers to recommend to the CEO the projects and programs that are most effective in meeting the organization’s goals and to eliminate those that are not aligned with the strategic goals of the organization.

Megaprojects: The Literature

Megaprojects have been characterized by size, duration, uncertainty, ambiguity, complex interfaces and integration, and significant political and external influences. The Federal Highway Administration (FHWA) characterizes a megaproject as any project of \$1 billion or more in size or a project of a significant cost that attracts a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and state budgets. *Mega* also connotes the skill level and attention required to manage the project successfully (Capka 2004). Megaprojects can also be defined as “initiatives that are physical, very expensive, and public” (Altshuler and Luberoff 2003).

The Big Dig was characterized as a megaproject not only by its cost, at more than \$14.8 billion, but also by its construction duration of more than 15 years and its heavy dependence on specialized infrastructure and unique and complex technology. As J. Richard Capka, FHWA deputy administrator and former Big Dig CEO, explains:

Before one embarks on a mega project whether as an owner, sponsor, lender or contractor, or in any capacity, it is imperative to understand what makes a mega project unique.

(Capka 2004)

Allen Sykes, an international adviser on megaprojects, outlines nine characteristics that distinguish megaprojects from other large but less complicated projects (Sykes 1998): (1) size and the likelihood of multiple owners; (2) public opposition to the likely social, economic, political, and environmental impacts; (3) time—a decade or more to plan, design, finance, and build; (4) located in remote and/or inhospitable areas; (5) potential to destabilize markets because of the demand on labor and supplies; (6) unique risk, especially when the project spans economic cycles; (7) financing difficulties; (8) insufficient experience, especially in managing complex undertakings; and (9) career risks, because most of the undertakings do not advance past the planning stage and, therefore, pose an unpopular career course for senior managers. Although most megaprojects contain all nine characteristics, there are some exceptions.

According to Sykes, megaprojects fail not because of myriad design and engineering challenges but because leaders are unable to forge and hold together workable alliances with major stakeholders or to raise the necessary funds—problems that require significant political and organizational skills. He calls for an independent “project directorate” of experts to review each critical aspect of the project and report directly to the owner (Sykes 1998).

Megaprojects in the United States

The transportation sector accounts for more than 10 percent of the U.S. gross domestic product (GDP), behind only housing, food, and health care. Across the country, taxpayers are pumping billions of dollars into innovative transportation initiatives. As reported in the U.S. Department of Transportation’s *Agency Financial Report*, three major transportation initiatives will take place in the upcoming years to address the infrastructure needs of America’s future (USDOT 2010). These include:

1. The Next Generation Air Transportation System (NextGen) to replace World War II–era, ground-based radar technology with satellite operations, while ensuring the safe and efficient operation of the National Airspace System. As part of this long-term modernization project, in 2010 the Federal Aviation Administration (FAA) launched a full-scale, nationwide deployment of the satellite-based surveillance system called Automatic Dependent Surveillance-Broadcast (ADS-B), which tracks aircraft with greater accuracy, integrity, and reliability than the current radar-based system.
2. Through an initial \$8 billion investment, the groundwork has been laid for development of an efficient, high-speed passenger rail network of 100- to 600-mile intercity corridors that represent an essential component of a modernized, nationwide system.
3. DOT’s third major endeavor is the nation’s first Livable Communities Initiative, which will measurably enhance the quality of life for families,

workers, and communities across America. The program offers more public transportation choices and more commercial and residential development around transportation hubs. Local cities and towns will use the funds to integrate planning and design for livable communities.

During the past decade, the U.S. Department of Transportation identified more than 33 federally funded megaprojects—that is, construction projects costing in excess of \$1 billion—currently under way or completed in the United States. The list included such diverse endeavors as the \$4.5 billion Los Angeles Red Line, Salt Lake City’s \$1.6 billion I-15 reconstruction project, the \$5.0 billion Miami-Dade International Airport expansion, the \$2.2 billion New St. Louis Mississippi River Bridge connecting Illinois and Missouri, the \$2.5 billion Woodrow Wilson Bridge connecting Maryland, Virginia, and Washington, D.C., Boston’s \$14.8 billion Central Artery/Tunnel Project, and the \$1.7 billion Miami Intermodal Center.

Megaprojects around the World

Megaprojects are growing at a fast pace, not only in the United States but in all corners of the world. China, Brazil, the Middle East, and other developing regions account for nearly half of the most costly projects in the world. Some recent projects under way include the \$25 billion Crossrail Project in London, presently the largest rail network expansion project in Europe; the \$8 billion Trans-Afghanistan pipeline, which reached agreement between Afghanistan and India in 2012; and the \$40 billion Songdo Sustainable International Business District Project in Seoul, South Korea.

In both developed and developing countries, major megaprojects supported by the World Bank and other development banks have been completed or are under way. Remarkably, 90 percent of new-country assistance and partnership strategies at the World Bank emphasize climate action. Bank-funded low-carbon-growth studies in Brazil, China, Colombia, India, Indonesia, Mexico, Poland, and South Africa are supporting efforts to implement national climate change action plans.

The diversity of these major megaprojects and the benefits are demonstrated by the following examples:

- The World Bank has taken up a megaproject, touted as the first of its kind, for conserving the rich biodiversity and boosting socioeconomic development of the Sundarbans area in West Bengal.
- In China, by strengthening the Yangtze River Dikes, about 75 million people and more than 1.4 million hectares of farmland have been protected from flood damage.
- In Cameroon, 1.6 million people benefited directly from improved infrastructure, including more than 98,000 from improved access to educational facilities.

- In the Dominican Republic, electricity losses were cut by 14 percent during 2005–2008 under a regional Caribbean project on secure and clean energy.
- In Hungary, pollution in the Danube River Basin was reduced by more than 50 percent by expanding the wastewater treatment capacity of utilities during 2000–2007.
- In Malawi, there was a 12 percentage point decline in the poverty head count, from 52 percent in 2005 to 40 percent in 2008, attributed in part to infrastructure development.
- In the Philippines, about 5 million residents of Bicol, who had suffered power shortages because of typhoons, benefited from a stable power supply in 2008.
- The first Low-Carbon Development Policy Loan for Mexico (\$401 million) was approved in November 2010.
- A development policy loan for Poland (\$1.11 billion), approved in June 2011, supports the energy efficiency and renewable energy components of the Energy Policy of Poland until 2030 program.

CHARACTERISTICS OF MEGAPROJECTS

Megaprojects are not just characterized by their cost or complexity; there are many characteristics, as reflected in literature and practice, and for many developing countries a megaproject may be well under the FHWA characterization of \$1 billion yet still be considered a megaproject as contrasted with the country's gross national product. Recognizing and understanding the dynamics of megaprojects is a critical first step in planning for the uncertainty and ambiguity that make managing megaprojects a tremendous challenge. Highlighted as follows are 25 common attributes of megaprojects, along with some less obvious characteristics that were unique to the Big Dig.

1. Long Duration

Megaprojects are often of long duration—between 3 and 15 years or longer for some oil and gas concessions, which can run as long as 20 to 40 years. One of the longest concessions in history was the D'Arcy Concession, a petroleum oil concession that was signed in 1901 and gave D'Arcy the exclusive rights to prospect for oil in Persia (now Iran) for 60 years.

The length of the project alone creates multiple unknowns, ambiguity, uncertainty, and risk that do not exist in projects of much shorter duration (Capka 2004; Haynes 1996, 2002; Merrow 1988). Long projects also require very large amounts of resources including labor, financing, supplies, and equipment (Hall et al. 2001). Calculating the cost and availability of steel 14 years into the future is difficult enough, let alone determining whether the soil conditions will be sufficient to build complex structures based on erosion over time.

According to a 2002 GAO report, *Preliminary Information on the Timely Completion of Highway Construction Projects*, the time required to complete an average highway project varies widely. The time required depends on the size of the project, its complexity, and the public interest in the project. Some projects may take as few as 3 years, while others may take more than 13 years. Because there was no gold standard on time to complete projects set by the FHWA, the Big Dig's completion date evolved over time. While original projections predicted the year 1998, in 1995 the finish date officially crept to 2001, with many observers anticipating further changes to the schedule at that time, resulting in a new estimated completion date of 2004 and a final completion date of 2007—almost ten years later than originally predicted.

2. Scale and Dimension

Though the FHWA has characterized a megaproject as costing more than \$1 billion, the cost of a megaproject is relevant only as it is contrasted with the size of the location or country where it is built. For instance, the Mozal Project, an aluminum smelter plant project in Mozambique, pales in comparison to the size of the Big Dig and the English Chunnel, yet its earliest estimates at \$1.4 billion approached Mozambique's GDP of \$1.7 billion. Since 2001, Mozal has grown to a size of \$2.5 billion and is one of the biggest aluminum foundries in Africa. Others define megaprojects broadly as projects that transform landscapes rapidly, intentionally, and profoundly in very visible ways and require coordination and application of capital and state power (Gellert and Lynch 2003).

3. Type of Industry and Purpose

Megaprojects have been categorized by type of industry and purpose. Most definitions are imprecise and tied to specific types of projects. For example, oil and gas projects are almost always characterized as megaprojects regardless of the size. The literature and research reflect five typical types of megaprojects that include the following:

1. Infrastructure projects such as roads, bridges, water security, tunnels, and dams
2. Extractive industries such as oil and minerals
3. Production industries such as agriculture, rubber plantations, and exports
4. Research and development including software design, biotechnology, and aerospace innovation
5. Consumption such as travel and tourism, film festivals, Olympic stadiums, and entertainment complexes

4. Design and Construction Complexity

Engineering is the art of modeling materials we do not wholly understand, into shapes we cannot precisely analyze, so as to withstand forces we cannot properly assess, in such a way that the public has no reason to suspect.

—Dr. E.H. Brown 1967

There are multiple definitions of project complexity, for all types of projects, but for infrastructure the most common definitions include an analysis of design and construction complexity. *Design complexity* is described in two ways: First, it can be described by the number of steps it takes to complete a final product. For example, the tunnel portion of the Big Dig contained a number of phases including conceptual, environmental feasibility and sustainability, geotechnical, structural, tendering, supervision, operational, and maintenance. The second way is through design criteria such as performance parameters, variability, vulnerability and ergonomics. The tunnels also required a number of engineering specializations including civil, electrical, mechanical, and environmental. The tunneling portion was more complex than the roadways and, thus, the degree of complexity can vary from one contract to another in a megaproject.

Construction complexity is generally defined in terms of integration and organizational complexity. For example, the first working definition of Integrated Project Delivery (IPD) was established in May 2007 by the AIA California Council Integrated Project Delivery Task Force. In addition to the design phases it includes the following phases: implementation documents phase (construction documents), buyout phase, agency review phase, construction phase, closeout phase, and facilities management. Megaprojects generally require complex construction integration and technical, resource, and materials management characterized by a long time frame and numerous interfaces among multiple contractors and third parties.

5. Sponsorship and Financing

Megaprojects generally have complex financing schemes that involve combinations of debt, equity, grants, bonds, notes and in-kind contributions, and multiple sponsors from both the public and the private sectors. Chapter 2 focuses on the financing of large-scale projects with diverse financing sources that change over time. Generally, there is little time to look for new financing when costs increase and budgets are underestimated, as is frequently the case on megaprojects (Flyvbjerg et al., 2003). Walking away from a partially built project is rarely an option. Lenders normally charge higher interest rates for new debt, and equity sponsors are not always willing to contribute after construction has commenced. In public projects, government funds may impact the local business climate and the ability to fund other projects. Funding requirements can affect a state's bond rating and the ultimate cost of

borrowing. The dramatic increase in cost on the Big Dig and the payments for debt that continue until 2039 illustrate the unique funding issues in megaprojects and the challenges that projects face in remedying these problems.

6. Life Cycle

The project management literature characterizes projects by various phases known as the *project life cycle*. Complex projects are much more difficult to define in terms of the traditional project life cycle, as the processes are repetitive and recurring throughout the life of the project and it is difficult to define where one phase ends and the next begins. Initiation on some parts of the project may be occurring very late in the life of the project while closure has already been achieved on other parts of the project. The Big Dig closed on several major portions of the project early on, including the completion of the Ted Williams Tunnel in 1995, while the significant demolition, excavation, and construction had not yet begun on the I-93 underground tunnel through Boston.

7. Long, Complex, and Critical Front End

The long front end of the Central Artery Project was best described by Fred Salvucci, one of the project's chief visionaries and master planners of the Big Dig:

... It was a 15 year process from initial authorization to final approval. The Project was first authorized by Congress in 1976, but it took until 1991 when the Environmental Feasibility study was officially submitted to the Federal Highway Administration for the Project to be finally approved.

(Salvucci 2012)

At the outset, the level of ambiguity of large complex projects tends to be extremely high. Most projects of this type go through a long "search" period during which both the problem and the solution are sorted out. During this period, some of the players are already known but many more are yet to be identified. In a significant number of cases, this period of preliminary search lasts for decades. For example, many transportation infrastructure projects and facility development projects are in the air for decades before the timing is right to move to some form of concrete proposal for action.

The search phase may be initiated by a perceived need or opportunity or by a signal from an important player that he or she is open to proposals for a particular project or type of project. Governments create opportunities and signal their interest through policy statements and through changes to the institutional framework. This phase is very entrepreneurial. Not only are the problem or opportunity and the solution being sorted out, but coalitions of players are also taking form. The pace is broken and sporadic. Projects often

go into limbo after periods of considerable exploratory activity. Exploratory processes often lead to dead ends and are abandoned, at least temporarily.

In their research on projects, Miller and Hobbs (2005) learned that the long, complex, and critical front end of projects, sometimes called the *exploratory phase* or *formulation phase*, was essential to ensuing project success. Their research revealed that the front ends of projects were very long—seven years on average—and often very expensive (up to 33 percent of the total budget). Moreover, the management of this phase was critical and showed significantly more impact on project performance than the management of the engineering, procurement, and construction phases. This phase is often preceded by an extensive lobbying phase conducted by different interest groups. Projects can go through lengthy periods of time to vet both the problems and the various scenarios for solutions. The Big Dig had one of the longest exploratory phases in U.S. history, and the issues raised were technological capability, environmental feasibility, funding availability and political support, and risk, among other concerns (CA/T 1990).

During this exploratory phase, the problems facing major public investment projects can be interpreted in terms of deficiencies in the analytical or the political processes preceding the final decision to go ahead and the interaction between analysis and decision makers in this process (Samset et al. 2006). Such processes are often complex, disclosed, and unpredictable (Miller and Lessard 2000). During this phase, the environmental feasibility studies are completed and approved. Initial testing is commenced and financing is approved. Permitting, licensing, and fees are secured.

8. High Public Profile

Large projects have a high profile with the political subdivisions of the government and the public and are often the focus of government regulators, the media, and public and private audits. The active role of third parties, including local communities, may create conflict and disputes that must be addressed in a timely manner to avoid damage to the reputation of the project and its leaders. The ability to maintain the support of multiple and diverse stakeholders over a long period of time requires tremendous resources and an ability to address the ever-changing demands of stakeholders and the project environment. Researchers and practitioners have noted the public opposition to the likely social, economic, political, and environmental impacts of large-scale projects (Sykes 1998). Chapter 3 provides an overview of the political, technical, legal, economic, and environmental issues raised by stakeholders in megaprojects, as well as the necessity of developing a structure that is open to public participation and community involvement.

9. Public Scrutiny

In addition to a high public profile, high-performing projects are subject to intensive scrutiny. The project sponsor plays an important role in ensuring

that projects are scrutinized. The involvement of other stakeholders with diverse interests and perspectives in a governance structure that encourages scrutiny also contributes to the development and delivery of feasible projects; examples include risk and financial evaluations by those providing funding and environmental and social acceptability evaluations through diverse mechanisms of public consultation. Often, the ownership structure creates a context in which stakeholders with both the ability and the incentive to scrutinize projects have decision-making power. Rigorous scrutiny provided through diverse mechanisms contributes significantly to the development, selection, and delivery of feasible projects.

Large infrastructure projects are visible and contestable (Miller and Hobbs 2005). They are never truly private endeavors. Because of their visibility and their environmental, social, and economic impacts, these types of projects are always subjected to considerable public scrutiny and are frequently contested very actively by groups with widely varying interests and perspectives. Public scrutiny and contestability are central to the promotion of the public good. However, these can lead to perverse effects such as constituents pressuring politicians to renege on their commitments and projects being captured by interest groups and held for ransom.

Scrutiny was provided throughout the life cycle of the Big Dig through various entities, structures, and reporting requirements including the legislatively established oversight and coordination commission, dispute review boards, extensive press coverage, numerous internal and external auditors, the local community and businesses, and the project's wrap-up insurance program and trust fund.

10. Pursuit of Large-Scale Policy Making

Megaprojects are often preceded by large-scale policy making to accomplish major infrastructure challenges across cities, states, and countries (Bosso 1994; Tobin 2001). Luberoff and Altshuler provide fascinating insights into the political history of the Big Dig and the muddled aspects of public policy making (Luberoff and Altshuler, 1993, revised 1994).

Paul Schulman, an authority in policy making, argues that large-scale public policy represents the pursuit of objectives that cannot be fulfilled by a series of individualized, partial, and disaggregated steps (Schulman 1980). The particular tactics by which flexibility can be achieved obviously vary greatly among policy contexts, and different partisans will find some tactics more advantageous to them than others.

Especially for political reasons but also to some extent because of the nature of space exploration, NASA is said to have had to work at a large scale, or not at all (Schulman 1980). It took several decades to find out that giant nuclear power plants would be politically and economically unacceptable in most nations, by which time hundreds had been constructed throughout the world for several hundred billion dollars. The error was irreversible, the

learning slow, and the cost enormous. Policy makers could have pursued much smaller reactors, using different designs that would have been less expensive, more flexible, and apparently incapable of catastrophic meltdown (Morone and Woodhouse 1989). Nuclear power is presently supported by the federal government in the United States, and is described as one of the safest forms of energy production, despite the nuclear meltdown brought on by the 2011 tsunami and earthquake in Japan.

Large-scale policy making was essential on the Big Dig to accomplish the master plan to replace the aboveground highway with an underground tunnel and to connect the interstate with both the airport and the City of Boston, while at the same time addressing multiple environmental and community concerns.

11. Project Delivery and Procurement

Complex megaprojects require innovation in contracting and procurement to address the allocation of risk during the early planning stages. Megaprojects are known for varied and unique delivery methods. Project delivery is a description of the contracting methods and relationships between the owner, designer, and contractor required to design and build a construction project and includes planning, budgeting, financing, design, construction, and operations (Sanvido and Konchar 1999). In the United States, individual state departments of transportation (DOTs) typically manage and control the full cycle of project delivery, from inception through construction. They may elect to contract with engineering consultants or construction contractors to perform various services related to the project development process.

Some of the more common project delivery methods include design-bid-build (DBB), design-build (DB), construction manager/general contractor at risk (CMR/GC), and build-operate-transfer (BOT). It is contended that DB projects provide greater opportunities for small business (as subcontractors) to perform substantial portions of such projects (FHWA 2006).

On the Big Dig, the more traditional DBB delivery method was used to separate the procurement of designers from the procurement of the contractors. In this delivery method, the project owner or the selected designer furnishes to the constructor design documents, which the constructor is obligated to follow. Essentially, the designer warrants to the constructor that the design is in compliance with the contract documents. As discussed in later chapters, the mechanism chosen for project delivery on the Big Dig was a source of concern due to the constant tension between design and construction. By combining these two functions into a centralized management system, such as DB, the constructor is responsible for both design and construction, eliminating the potential for conflict and numerous disputes.

12. Continuity of Management

It is significant that there is less likelihood of maintaining continuity of management in long-duration projects, particularly in public projects during

Table 1.1 Massachusetts Governors Serving during Big Dig Life Span

Project Phase and Dates	Governors
Conceptual, 1970s–1980s	Sargent, Dukakis, King, Weld
Procurement and engineering/design, 1985–2004	Dukakis, Weld, Cellucci, Swift, Romney
Construction, 1991–2006 (substantial completion)	Weld, Cellucci, Swift, Romney
Operation and maintenance, 1995–2095 (100-year life span of cable-stayed bridge)	Weld, Cellucci, Swift, Romney, Patrick

which administrations change frequently and new policy and agendas develop over time. Realistically, there is also a burnout rate, as it is often difficult to manage the pressures, political realities, and obstacles that accompany the role of project management in a megaproject. As an example, eight governors served Massachusetts during the lifetime of the Big Dig, including the long conceptual phase of the project (Table 1.1). That in turn meant that several project directors and program managers were appointed, depending on the particular expertise viewed as essential by the appointing authority. The lack of continuity was raised as a concern at the Big Dig (Board 2003). Though the private-sector management consultant remained constant throughout the life of the project, the state government entity responsible for oversight changed in 1997, when the Massachusetts Highway Department (MHD) was replaced by the Massachusetts Turnpike Authority (MTA), the ultimate operator of the project. This created a major gap in institutional knowledge and expertise during the peak years of construction. There are some who contend that frequent change in high-level leadership is a good thing, as it can bring creative ideas and a fresh look at the project.

13. Technological and Procedural Complexity (Urban Design)

Large projects are famous for new technologies and the new risks these technologies bring. Projects without precedent can bring many challenges including safety, health and environmental risks, and the potential for increased costs and extended schedules during the testing and implementation phases of the project. Technologically complex projects require expertise that may not be readily available and the use of cutting-edge and emerging design and construction techniques and methodologies. The complexity of urban design and unknown subsurface conditions is well documented in numerous engineering reports, audits, and the project management literature (Hatem 1998).

The Big Dig was known not only for its technological innovation but also for the development of innovations in business organization, development, financing, design, execution, and operations. As a public entity, the Big Dig

was subject to increased project scrutiny to ensure the project was representing the public interest. Traditional models of project design and execution would not have worked due to the many complex processes and procedures, the need for shared risk and responsibility, and the difficulty of managing change and innovation in a structured environment.

14. Organizational Structure

Complex projects often have unique organizational structures with multiple levels of authority that require both vertical and horizontal coordination. On the Big Dig, the organization was originally managed on the public side by a project director and on the private construction side by a program manager, with the introduction of an integrated project organization during its peak years of construction. Typical of large-scale projects, the Big Dig was organized by area. The area managers were often assigned geographically and were responsible for administration of their area work as well as coordination among different area work groups. The lower-level or resident and field engineers were assigned to specific contracts and would maintain direct responsibility for design and construction decision making on those contracts.

15. High Degree of Regulation

Megaprojects tend to produce critical infrastructure that is highly regulated. The potential for catastrophic loss and breach of infrastructure security tends to be high on megaprojects as evidenced by the extensive regulation of nuclear power plants, bridge and tunnel projects, gas and oil pipelines, and energy resources. The Department of Homeland Security, the Nuclear Energy Regulatory Commission, the Environmental Protection Agency, the Department of Energy, and the U.S. Department of Transportation all play major roles in critical infrastructure oversight and enforcement. The U.S. Department of Homeland Security's National Infrastructure Protection Plan (NIPP) provides a unifying framework that integrates a range of efforts designed to enhance the safety of critical infrastructure in the United States. The overarching goal of the NIPP is to build a safer, more secure, and more resilient America by preventing, deterring, neutralizing, or mitigating the effects of a terrorist attack or natural disaster and to strengthen national preparedness, response, and recovery in the event of an emergency. The Big Dig had an extensive emergency response and critical infrastructure and security program that operated 24/7 to ensure the safety of all workers, project employees, and local society impacted by the project.

16. Multiple Stakeholders

Megaprojects are almost always embedded in a complex network of public interests due to the abundance of stakeholders with connections and influence

in the project. Large numbers of stakeholders create management challenges that don't exist in smaller projects (Chinyio and Olomolaiye 2010; Altshuler and Luberoff 2003; Miller and Lessard 2000). Public and private interests often diverge in projects where the public interest can be compromised by the private-sector stakeholder's profit motivations. The impact of stakeholders on the Big Dig was enormous in terms of mitigation efforts required to protect the interests of local residents, businesses, the general public, and government agencies. Participation of stakeholders in the daily life of the project was essential, and there was a constant need to manage the balance between the shifting interests and influence of stakeholders both internal and external to the project (Goodijk 2003).

17. Dynamic Governance Structures

Governance of megaprojects has become an emerging issue with the expansion of globalization, and research is desperately needed to develop enhanced government frameworks and hybrid models for governance that involve greater local community participation and adherence to principles of distributive and procedural justice (Levitt et al. 2009).

As described in Chapter 4, the governance models used for megaprojects are very different from the traditional hierarchical structure of most corporations and nonprofit organizations such as schools, medical facilities, and government agencies. On megaprojects, all roads lead to governance because the root cause of most problems is weak governance, nonexistent governance, or the wrong governance structure. Multiple governance structures that coexist within the organization are common in large-scale projects, as are nontraditional modes of decision making and oversight. For instance, the Big Dig's governance structure included federal oversight, an owner's board of directors, an owner's project director, and a program manager led by the project's private joint venture consultant, among numerous other decision-making and approval authorities and several hundred project teams that needed to be integrated and coordinated.

On the Big Dig, governance was compounded by the fact that the government relied on the project's management consultant to complete the preliminary designs (which formed the basis for hiring the final design firms), monitor the work of the final design firms, oversee the soils testing and remediation work, prepare the construction bid packages, oversee the construction contracts, negotiate claims and changes, and manage construction in the field, among many other responsibilities.

18. Ethical Dilemmas and Challenges

In today's fast-growing global environment, development of a good ethical framework is part of the human condition. Ambition and the drive for greatness are a constant struggle against greed and self-promotion. As a result,

there is an increasing need for project management professionals to learn more about the importance of ethics, particularly as they impact megaprojects. Ethical dilemmas can arise from poor governance structure, conflicting roles of project participants, a lack of transparency, failure to involve stakeholders, relationships with businesses and the community, and environmental conditions. To instill a confidence in the project management profession, PMI developed the PMI Code of Ethics and Professional Conduct, which all PMI members and credential holders must sign (PMI Ethics). Ethical conduct is at the heart of the operation of all megaprojects, and the success of a project depends upon high ethical standards.

19. Consistent Cost Underestimation and Poor Performance

Large, complex projects have characteristics that make them extremely challenging to estimate and which estimators should always consider when reviewing costs assumptions. These include the stretching of available resources to the limit—labor, material, management skill, and information systems, and the management of contingencies and inflation. Research bears out that large-scale projects are consistently underestimated (Anderson et al. 2007; Luberoft et al. 1993; 1994; Flyvbjerg et al. 2002). The Big Dig, the English Channel Tunnel, Germany's Inner-City Express, and the San Francisco Bay Bridge all were dramatically underestimated. The reasons behind these huge overruns vary from project to project; however, cost overruns tend to be a distinguishing characteristic of megaprojects.

The literature on megaprojects also reflects that these mammoth projects are plagued with poor results. Researchers have indicated a variety of factors that contribute to the high rate of failure of megaprojects. Extensive studies on the reasons for poor performance of large-scale projects have concluded that the following are significant factors: (1) political bias, (2) unrealistic original cost estimates, (3) changes in design, (4) low contingencies, (5) underestimation of geological risk, (6) quantity and price undervaluation, (7) political risk and expropriation, (8) technological risk, and (9) underestimation of the length and cost of delays (Flyvbjerg et al. 2003a; Flyvbjerg et al. 2003b).

20. Risk Management in Complex Projects

Complex megaprojects face emergent risks that are not usually present in traditional projects. Therefore, risk management requires a shared vision, partnering, and an integrated structure to mitigate and eliminate the enormous risk potential. The literature has shown that major risks in complex projects include (1) political risk that results in uncertain financing and a significant decline in potential revenues, (2) potential for catastrophic loss, (3) complex engineering and design risk, and (4) substantial unknowns that impact budgets and schedules. The Big Dig had one of the world's

largest owner-controlled insurance programs to manage 132 major contracts at its peak and thousands of subcontracts. As described in Chapter 9, the centralized risk management, safety, and loss control program resulted in substantial benefits to the project due to its unique organizational and governance structure.

21. Socioeconomic Impacts

Megaprojects tend to produce significant socioeconomic effects that can have both positive and negative impacts. Diverse stakeholder interests create challenges for project owners that must be addressed before projects can be approved and initiated. The Big Dig created an unusual amount of public attention and criticism due to its sheer size, technological feats, environmental concerns, and visibility. Interest groups have held projects hostage throughout history, sometimes resulting in the abandonment of projects due to the difficulties in overcoming extreme public pressure caused by concerns over neighborhood disruption and safety, health, and environmental concerns. Rejected projects include cancellations by regulators, courts, or local authorities; abandonment by utilities; or projects placed on hold due to regulatory, financial, or other problems. Concerns about global warming played a major role in cancellation of five proposed Florida coal plants, seven proposals in Western states that have newly implemented strict carbon regulations on coal, and numerous highway projects in San Francisco, Atlanta, New York, and Philadelphia (USDOE 2012).

22. Cultural Dimension

Megaprojects are known for unique cultural environments. *Culture* is defined broadly in project management theory to include the “people” side of project management (Cooke-Davies 2002; Pinto 2009). Since megaprojects are made up of numerous participants including public officials, citizens, developers, designers, contractors, and community organizations with different values, perceptions, and needs that often cross countries and continents, it becomes a significant factor in the structure, organization, and governance of the project. Project culture has many dimensions and includes differing political, strategic, economic, and ethical backgrounds that must be harmonized. Cultural challenges on the Big Dig included integrating diverse project teams, philosophies, and practices through partnering and collaborative efforts.

23. Systems and Methodology Complexity

Megaprojects are not just unique because they cost more but because they require extensive amounts of financial, human, and material capital and are designed to address complex systems that involve many interrelationships

and interdependencies, within multiple systems and multiple feedback loops (Haas 2008). As an example, schedule alone on large projects often involves multiple critical paths and numerous interfaces. This requires a special skill and expertise that cannot be easily found, as smaller project experience rarely can meet the capabilities required for large-scale projects. Project configuration with multiple activities, processes, and interfaces only adds to the systems complexity requiring the concurrent application of multiple management methodologies. Often, engineering talent can be hard to find, considering the unique and complex structure of megaproject decision making and organization.

24. Environmental Impact

Megaprojects are inundated with environmental challenges, as evidenced by the Big Dig's extensive Environmental Feasibility Study. Though much smaller projects face environmental issues, the sheer magnitude of these problems on a megaproject necessitates extensive up-front planning during the conceptual and preliminary engineering phases of the project and continuous monitoring through all project phases until transition of the project to the ultimate owner or operator. In accordance with state and federal law, the Big Dig required an extensive Environmental Assessment, which took years to complete before the project received final approval to proceed. The environmental assessment included the impact on the 1.5 million people that entered the city each day, along with the more than 600,000 residents of Boston and the numerous businesses that lined the artery. Issues involving air quality, noise and dust control, traffic congestion, rodent control, and health and safety were analyzed, with recommendations for mitigation. The environmental impact not only must be planned for many years in advance but also must be monitored and controlled through all phases of the project.

25. Collaborative Contracting, Integration, and Partnering

All organizations have moved toward a collaborative environment, but it is probably no more evident than in the management of large-scale projects. Examples of collaboration include concurrent engineering, which is a work methodology based on the parallelization of tasks and refers to an approach whereby all functions are integrated to reduce the time needed to bring a product to market. On the Big Dig, engineers utilized concurrent engineering in lighting, utility placement, and air and heating ducts. Other collaborative efforts included partnering as a dispute resolution technique, integrated risk management, safety, health and insurance programs, integrated change control, integration of the project's utilities program, and the establishment of an integrated oversight coordination commission (CA/T/OCC 1998).

MEGAPROJECT FRAMEWORK

To describe a megaproject in isolation from the concepts, practices, and theory that gives it life would be a difficult task. Thus, throughout this book you will find examples of real-life case studies; application of project management strategy, policy, standards, processes and theory; and analysis of conflicts and problem-solving techniques used by the project's numerous stakeholders. The Big Dig's megaproject framework, illustrated in Figure 1.3 and defined in Table 1.2, best describes the context in which the project operated and the various elements that were critical in moving the project from the conception phase through to completion.

1. Project Management in Practice

In recent years there has been a marked surge in professionalism in project management through educational programs, the awarding of university degrees in project management, and recognized certifications by the professional organizations. Much of project management practice has developed from the processes and procedures developed by the professional standards organizations. The Project Management Institute (PMI), in the United States, is recognized worldwide for its project management standards. Other widely respected professional standards organizations include the U.K. Association for Project Management (APM), the International Project Management Association (IPMA), and the Australian Institute of Project Management (AIPM).

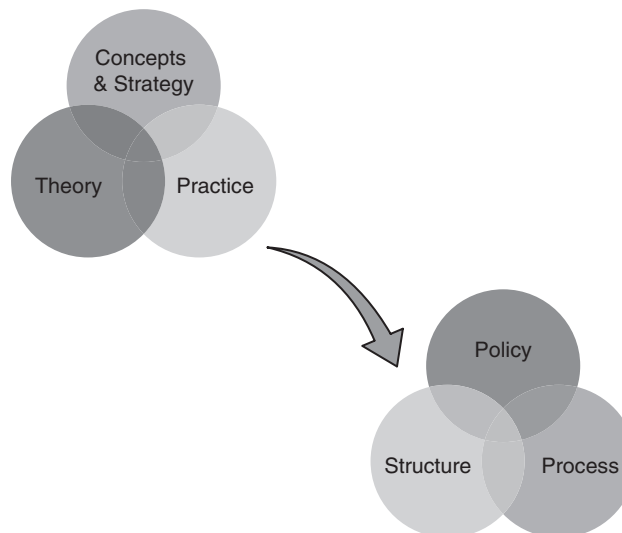


Figure 1.3 Megaproject Framework

Table 1.2 Megaproject Framework

Framework Elements	Definition
1. Concepts and Strategy	A direction in a project that contributes to the success and survival of the project in its environment and aligns with the goals of the project's parent organization.
2. Theory	A theory derives primarily from concepts and causal relationships that relate these concepts (Whetten 1989) and thus contributes to understanding as well as providing a prediction of future behavior (Koskela and Howell 2000).
3. Practice	Project management practice is a specific type of professional or management activity that may employ one or more techniques or tools. The practice of megaproject management is broken down into the following three categories: (a) policy, (b) process, and (c) structure.
a. Policy	A definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions.
b. Process	Establishes the total scope of the effort, defines and refines the objectives, and develops the course of action required to attain those objectives. The <i>PMBOK</i> ® <i>Guide</i> (2013) states that projects are composed of two kinds of processes: project management processes and product-oriented processes (which specify and create the project product). Project management processes are further divided into initiating, planning, execution, controlling, and closing processes.
c. Structure (1) Financial structure: How the project is financed, including the sponsors, the type of financing, and the revenue stream (2) Organizational structure: Defines who reports to whom and what the responsibilities of each position are (3) Governance structure: An oversight and decision-making function	A framework of policies and procedures that projects use to break a project organization into manageable activities. This process involves establishing a financial structure, an organizational structure setting specific job responsibilities, a governance structure that creates a line of authority for managers, and a decision structure for major issues or opportunities.

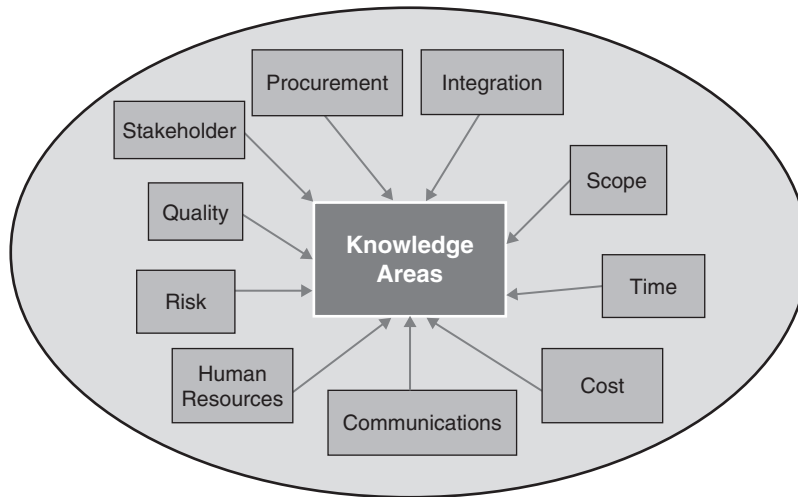


Figure 1.4 PMBOK® Guide Knowledge Areas

Source: Project Management Institute (PMI). 2013. *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*—Fifth Edition.

The *PMBOK® Guide* is a global standard from the Project Management Institute (PMI) that defines project management as “[the] application of knowledge, skills and techniques to project activities in order to meet the project requirements.” The *PMBOK® Guide* represents what is recognized as common practice in managing projects, however, project managers must adjust their management method for the unique qualities of each project. The *PMBOK® Guide* defines ten areas of knowledge, shown in Figure 1.4, that contain the processes that need to be accomplished within its discipline in order to achieve an effective project management program. Seven chapters of the book are devoted to seven of the ten knowledge areas as they were applied on the Big Dig (stakeholder, scope, time, cost, risk, quality, and integration management). Three knowledge areas (communication, human resources, and procurement) are discussed in various chapter sections throughout the book. It is important to note that the application of the knowledge areas, and the tools and techniques used, can vary widely between large-scale projects, where there is more complexity, ambiguity, uncertainty, and greater risk, and smaller projects, where there is less uncertainty and thus less risk. Though the Big Dig recognized each of these knowledge areas, in applying these areas, the standards, processes, and procedures required were very different from smaller-scale projects, where there is less uncertainty, complexity, and risk.

2. Project Management Strategies

A strategy in the context of project management can be defined as the direction and scope of an organization over the long term that achieves

advantages for the organization, through its alignment of resources within a challenging environment, to meet the goals of the organization and to fulfill stakeholder expectations. To be successful, projects must always be aligned with the strategic goals of its parent organization. Numerous strategies were used to accomplish the goals of the project's owner, but a few of the more important strategies are summarized as follows.

1. Develop a Project Vision Key to the success of the project was a strategy aligned with the vision of the project owner, which was to develop an infrastructure that included a roadway, bridges, and tunnels that were safe, reliable, and affordable for the benefit of the public stakeholders. Reaching that vision required a strategy from the conceptual phase of the project through to project completion.

2. Determine a Political Strategy From the outset of this mammoth project, concern was high that the ever-increasing cost of the project would impact public support and funding. A political strategy was also required to deal with the numerous stakeholders with diverse interests and influences that required numerous mitigation efforts.

3. Evaluate Project Management from a Benefits Realization and Entrepreneurial Approach A cost-benefit analysis is critical in convincing the project owner and sponsors that the project is worth doing and will produce benefits beyond just the building of a physical structure. On the Big Dig, these benefits were realized in the form of dramatic reduction of traffic congestion; replacement of an aboveground highway with a more efficient, environmentally safe underground tunnel system; and improvement of air quality through the establishment of green space.

3. Project Management Theory

Projects have been embraced across many organizations and within many sectors as the dominant framework for carrying out unique, dynamic, and temporary actions (Dinsmore and Cooke-Davies 2005; Turner 1999a). Though projects have existed for centuries, it was in the 1950s that organizations started to systematically apply project management tools and techniques to complex engineering projects (Johnson 2002). There is now widespread agreement on the processes and tools for managing projects; however, there is still a lack of agreement on what constitutes project management theory (Shenhar and Dvir 2007; Morris 2004; Turner 1999b). Meanwhile, the field of project management, as a research and academic discipline, has seen a significant increase in trend analysis in recent years (Morris et al. 2011). Based on the growing literature, there has been pressure to better shape the theoretical basis of the subject and to make project management research more relevant to managers, sponsors, policy makers, and others concerned

with the management of projects, without diminishing the standards of academic rigor (Morris et al. 2011).

This book examines the project management research to understand the context in which the Big Dig was conceived and executed. Though, typically, project managers look to the international standards bodies for guidance in managing projects, project managers also must consider new methodologies and theories based on the unique attributes of each project. These newer methodologies can be applied concurrently with traditional theory. In other words, both new approaches and traditional processes can integrate effectively within the same project. For example, there is an emerging view that uncertainty caused by environmental turbulence and changing requirements can be resolved by using creativity, intuition, and tacit knowledge built up over time and through experience (Leybourne 2009).

As experience shows, megaprojects can have tremendous impacts on local communities and even countries; however, there are limited opportunities to gain knowledge on best practices and lessons learned about these projects. As illustrated throughout this book, project managers, in the absence of experience in a particular matter or methodology, often have to draw upon intuition or project management theory. Both the desire to maintain control of the decision-making process and the lack of experience and know-how foster a situation in which improvisation is common (Miller and Hobbs 2005).

In recent years, a shift has taken place from the rigid, process-oriented approach to project management to a more behavioral (Jaafari 2003; Snider and Nissen 2003) and improvisational approach (Leybourne 2007). Improvisation has been defined as the practice of reacting and of making and creating. Improvisation is linked with aspects of time and, particularly, pressure to achieve to a demanding or compressed timetable, which is a typical attribute of most megaprojects (Leybourne 2008). Projects that are surrounded with uncertainty and complexity need to explore new ways of delivery outside of the hierarchical, structured approach of most project management regimes.

Improvisation as a developing theory of project management is not recognized universally by the professional bodies, including the U.S. Project Management Institute, the U.K. Association for Project Management, and the International Project Management Association.

In the software development field, a new methodology, known as *agile project management* (APM), has been developed to address the constraints of cost, time, and schedule. Similar to improvisation, APM is a shift from the traditional planning and reporting process approach of project management to a more flexible, informal approach that evolves over time. Both improvisation and APM draw on an intuitive feel for what will work in a given situation. *Intuition* is generally defined as the ability to acquire knowledge without inference or the use of reason. Thus, it is suggested that both experience and the buildup of tacit knowledge over time will assist the project manager or team members in assessing how to meet undocumented requirements of a given situation (Leybourne 2008). Further research is needed on the use of both improvisation and APM outside the software development field to

determine the role of these emerging project management methodologies in large-scale infrastructure development.

LESSONS LEARNED

The lessons from megaprojects can provide valuable tools and innovative ideas for the improvement of all projects. Some of the most important lessons learned about megaprojects from the Big Dig include the following:

1. Megaprojects can provide frameworks for structural decision making, risk analysis, managerial incentives, and investment choices that can be beneficial to all projects.
2. Megaprojects provide solutions to agency conflicts that exist in traditional corporate organizations through organizational, capital, contractual, and governance structure.
3. Knowledge enhancement, attitudinal development, and skill building are all major benefits of examining the unique characteristics of megaprojects.
4. Involving the public at the conceptual stage of the project and throughout the life of the project is essential to project success.
5. Lessons learned from megaprojects must be shared to assist in the development of global best practices for project management.
6. Complex megaprojects face emergent risks that are not usually present in traditional projects. Therefore, risk management requires a shared vision, partnering, and an integrated structure to mitigate and eliminate the enormous risk potential.
7. Megaprojects require collaborative contracting, integration, and partnering as a framework for success.
8. Megaprojects are critical to economic growth and prosperity in both developed and developing countries.

SUMMARY

There are many lessons to be learned from large-scale projects, and as you read the remaining chapters in this book you will see some commonalities among projects regardless of size, duration, industry, geographic location, sponsorship, or mission, as well as some unique aspects of megaprojects that cannot be easily duplicated. Research on megaprojects is desperately needed in the field of project management, and thus filling this need is an explicit goal of this book.

ETHICAL CONSIDERATIONS

In a report released in January 2008, the nonprofit Ethics Resource Center (ERC) revealed that 52 percent of federal, 57 percent of state, and 63 percent

of local government respondents witnessed violations of ethical standards, policies, or laws in their workplaces (ERC 2008). From the perspective of the USDOT's Office of Inspector General (OIG), having a strong culture of ethics in the workplace is central to promoting program effectiveness and preventing or stopping fraud, waste, abuse, and other irregularities. Effective internal controls and oversight mechanisms must be in place to detect and reduce instances of fraud that prohibit the transportation community from accomplishing its goals (Crumpacker 2009).

Ethics Violation: Boeing Case Study—Conflict-of-Interest Conviction

In 2003, the media reported that a Department of Defense (DoD) official had helped negotiate a plan to lease Boeing 767 commercial jets to the Air Force for use as aerial refueling tankers. The DoD official and Boeing's former chief financial officer were fired after internal investigations found they had violated DoD and company policies, respectively. The Boeing executive had communicated with the DoD official about possible employment with Boeing while the official still worked for the Air Force and before she recused herself from involvement with Boeing contracts. Both tried to conceal their misconduct (Crumpacker 2009).

Based on these facts, respond to the following questions:

1. Why does the conduct of both the federal official and the Boeing executive raise major ethical concerns? Whom do their actions impact, and what is the damage that could result if this conduct were permitted to continue unpunished?
2. In addition to ethical violations, does their conduct also constitute violations of the law? What is the difference between a legal and an ethical violation? Should the penalties be the same for both?
3. Should the government and Boeing also be penalized for the actions of their employees? If so, in what way?
4. Why is the cover-up of wrongful conduct often worse than the conduct itself? What are the benefits of full disclosure of unethical behavior?
5. What could Boeing have done to better educate its employees about ethical and legal violations?

DISCUSSION QUESTIONS

1. How can infrastructure development be used to advance and improve societal interests? As a project manager in a developing country where half the population lives on a dollar a day, what strategies would you implement to address poverty alleviation and social improvement?
2. Assume you are appointed by the U.S. Department of Transportation (USDOT) to serve as the project manager on one of the largest infrastructure projects in the history of the United States. What recommendations would you make to ensure transparency and oversight of this project?

List five questions you would need to ask of the USDOT before you could develop your recommendations.

3. Of the three major megaprojects to be implemented in the United States reported in the USDOT's *2010 Financial Report*, which do you think has the greatest risks and why? Be sure to include a brief analysis of technological, financial, construction, and operational risks. The megaprojects are (a) The Next Generation Air Transportation System (NextGen), (b) the high-speed passenger rail network, and (c) the first Livable Communities Initiative.
4. What are the types of risk that are inherent in long-duration projects similar to the Big Dig? How can these risks be mitigated at the inception of the Project? Give three examples.
5. How does the life cycle of a megaproject differ from that of a smaller-scale project?
6. Why does Paul Schulman, an authority in policy making, argue that large-scale project policy represents the pursuit of objectives that cannot be fulfilled by a series of individualized, partial, and disaggregated steps?
7. What is meant by project delivery? What makes it a unique characteristic of megaprojects?
8. Why is continuity of management important in megaprojects such as the Big Dig? Keep in mind that the Big Dig spanned the terms of eight governors of the state of Massachusetts.
9. Why do projects without precedent create greater risk? Projects are defined as unique and one of a kind. Does that mean that all projects are without precedent?
10. Describe three socioeconomic impacts that were produced by the Big Dig.
11. What are the essential elements in a megaproject framework? Distinguish between project management (a) practice, (b) strategy, and (c) theory by giving an example of each.
12. What is the role of the professional organizations such as PMI, APM, IPMA, and AIPM in the management of megaprojects?
13. Define *improvisation* and *agile project management*, and explain how they are alike and how they are different.
14. Why are public projects highly scrutinized? Give an example of how public scrutiny can be managed on a megaproject.
15. This chapter includes 25 common and not-so-common attributes of megaprojects. Can you think of two or three additional characteristics of megaprojects and, in particular, of the Big Dig that were not included in this long list?

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