The Big Dig:

Key Facts About Cost, Scope, Schedule, and Management

Bechtel/Parsons Brinckerhoff
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The Boston Central Artery/Tunnel Project (CA/T) is the largest and most complex urban transportation project ever undertaken in the United States. Dubbed the "Big Dig" by Bostonians, it is the result of more than 30 years of planning and 14 years of construction to replace the elevated section of the Interstate 93 Central Artery through downtown Boston with a much wider underground highway, and to extend the Interstate 90 turnpike to Logan Airport via a third harbor tunnel. The Big Dig ranks on a scale with the Panama Canal and the Channel Tunnel.

The CA/T comprises 161 lane-miles of interstate highway—over half underground. Its host of civil engineering firsts include the world's widest cable-stayed bridge, the deepest underwater connection in North America, state-of-the-art freeway segments built only inches above old public transit railways, an extensive deep-soil-mixing program to stabilize Boston's historic soils during construction, and an unprecedented ground freezing system to allow jacking of full-size highway tunnel sections. The project has already been widely recognized through dozens of awards for engineering and aesthetics.

Perhaps most remarkable, millions of residents and visitors have enjoyed continued access to the city during more than a decade of construction starting in 1991. Through it all, Boston's downtown financial and commercial district has stayed open for business and the needs of residential neighborhoods have been addressed. This engineering marvel will enable Boston and the state of Massachusetts to meet their critical transportation needs in the 21st century with a great sense of civic satisfaction and pride.

These major accomplishments have come at a significant financial cost—now estimated at $14.6 billion for completed construction. The price tag rose dramatically over more than two decades as the project was enlarged, redefined, and portions even put on hold by state officials to meet the many often-conflicting concerns of Boston's downtown business community, neighborhood and environmental groups, adjacent landowners, taxpayer groups, and federal agencies.

The Big Dig's cost has raised many questions over the years. Most recently, leaks and wall defects in the I-93 tunnels have also generated concerns. This paper will:

- clarify the roles and responsibilities of the management consultant, Bechtel/Parsons Brinckerhoff (B/PB);
- place the Big Dig's cost growth in historical, political, and economic context;
- review the project's program to identify and remedy leaks and wall defects; and
- offer a reminder of the many reasons why Democrats and Republicans, business and community groups, local residents and national transportation experts, have come together to support this project over many years.

Managing a Megaproject: Roles and Responsibilities

As the management consultant first retained in 1985 by the Massachusetts Highway Department (MHD) and, later, the Massachusetts Turnpike Authority (MTA), B/PB helped manage the Big Dig through 2005, following widely accepted industry standards. As specified in 16 separate contracts, B/PB was responsible for:

- providing preliminary design services;
- coordinating the performance of the final designers of record;
- coordinating the construction work of the various contractors;
- reporting on the project's overall cost and schedule; and
- providing recommendations to MHD and MTA for decision making

Throughout the life of the project, MHD and MTA determined what got built, when, and for how much. B/PB developed alternatives and provided its professional recommendations on the most practical, cost-effective solutions but was not been empowered to choose among them.

Contracts for the final design and construction were awarded by MHD or MTA. Contractors are contractually responsible to these Commonwealth entities for cost, schedule, and work quality. B/PB's job was to discharge the critical roles of construction administration, safety monitoring, and project oversight—including estimating contract cost, monitoring contractors for adherence to budget and schedule, overseeing the contractors' quality control, and regularly reporting this information to its customer.

B/PB's role as management consultant changed significantly in 1998, when MTA combined key B/PB personnel with those of the state in an Integrated Project Organization. MTA's goal was to streamline project management and decision-making and efficiently move the project from the design phase to construction.

On December 31, 2005, B/PB's role on the project ended under the terms of our contract.[1] All administrative and project oversight functions handled by B/PB reverted to MTA at that time. Except for a few tasks such as completion of some record drawings and some safety monitoring, MTA took over management of all remaining engineering and construction as well. B/PB continued to provide staff, under MTA's direction, to support services such as engineering, claims and changes (negotiating settlements with contractors over payments for scope changes); contract closeout (documenting completion of punch list items and final acceptance); parks construction, and systems commissioning (planning for ongoing operation of project facilities).

In early 2006, the Big Dig reached the critical milestone of "substantial completion," meaning that essentially all facilities required for beneficial use of the project, including roads, ramps, and tunnels, became open to the public. Contractors continued to work on small repairs and finishing touches, road paving, and park construction.

On July 10, 2006, a tragic accident took the life of a woman driving through a tunnel on I-90 when concrete ceiling panels fell and crushed her car. Immediately after the accident, B/PB offered its full support to Massachusetts Governor Romney, Massachusetts Turnpike Authority (MTA), the attorney general, and others who are working to investigate the accident, reopen the highway, and address public concerns. The accident is still under investigation.

[1] Work Program 15, February 1, 2001, Attachment A-1, section 10.0, "Duration of Work Program."

Following the accident, Massachusetts Governor Mitt Romney ordered a "stem-to-stern" safety review of Boston's highway system, including bridges and tunnels. The review was conducted by the independent engineering firm Wiss, Janney, Elstner Associates, Inc. On November 17, 2006, reporting on the firm's findings, the governor declared the system to be "fundamentally safe." Although the report cited some areas of concern, it found the Big Dig to be conservatively designed and fundamentally robust, with significant built-in redundancy.

Growth in Project Cost

The concept of the Big Dig, as it took shape in the 1970s and early 1980s, reflected the conviction of Boston-area leaders and public officials that the old Central Artery, the most congested roadway in America, was nearing the end of its operational life. The multiyear job of redecking or even replacing it threatened to strangle the city by disrupting traffic in and around the city of Boston. The alternative concept of using "slurry wall" construction methods to build a new underground artery while keeping the old roadway open in the interim, proposed by the state Transportation Department, offered a way to free the city from gridlock in the long run without bringing its economy to a standstill in the short run.

The initial cost estimate of $2.6 billion (in 1982 dollars) dated back to 1985, before B/PB was hired, and was based on a preliminary concept developed by state officials before detailed technical studies had been undertaken. In the years that followed, state officials followed a deliberate and time-consuming process of consulting with various interest groups, negotiating settlements to lawsuits, and modifying project plans to minimize real or perceived harm to the Boston community. This process made the design more sensitive to community needs and increased public acceptance, but the resulting mitigation measures made the project much more expensive to design and build. With every extension of the project schedule, inflation took a bigger bite. Local concerns were minimized by the fact that the federal government, at least in the early years, was covering up to 90 cents on the dollar through the Interstate Highway Program.

As a result of this process, the cost of the Big Dig has always been a moving target. For example, state officials significantly shifted the configuration of a proposed tunnel in Fort Point Channel in response to objections from a large manufacturer and to take account of federal wetlands and historic preservation rules. The new route in turn required a host of mitigation discussions and measures to satisfy affected businesses and landowners.

To take account of local concerns in East Boston, the proposed airport interchange was redesigned in 1987 and then again in 1988, only to provoke the ire of an exceptionally vocal and determined owner of an off-airport parking lot. The state did not succeed in resolving his demands until 1991.

The Charles River Crossing—required to connect the Central Artery with four other roadways—triggered an even longer debate over concept and design. B/PB engineers and state officials analyzed more than 50 separate design alternatives in an effort to satisfy opposition from a host of groups, including the state's own Metropolitan District Commission and the city of Cambridge. The final concept was not approved by state officials until 1994—11 years after it was officially proposed in the first Environmental Impact Report—at an added cost of a billion dollars.

In all, according to state officials, the project undertook more than 1,500 separate mitigation agreements, accounting for at least one-third of the CA/T project's total costs. The most authoritative history of the project concluded that "what stands out most strikingly is the

extraordinary difficulty and expense, yet supreme importance, of consensus-building." The study's authors, Harvard University scholars Alan Altschuler and David Luberoff, argued that "the most powerful explanatory factor" behind the rising cost of the Big Dig was

> a new paradigm (i.e. conceptual frame) that the state adopted for resolving conflicts between project beneficiaries and those negatively affected by project construction. . . . The traditional view was that large projects inevitably harm some bystanders, but that their self-interested objections should not be allowed to block the realization of broad public benefits—or indeed to drive up costs significantly. . . . Public projects are now subject to a multitude of environmental, citizen participation, and other regulations, and are far more vulnerable to legal challenges. As one consequence many fewer large public works projects go forward; but as another those which do are far more expensive—since their budgets include larger, often vastly larger, amounts for mitigation and compensation.[2]

Specific Cost Drivers

B/PB, working with state officials, has analyzed in much greater detail the specific drivers of cost growth on the project. This analysis shows that the single biggest contributor to rising costs was inflation, which by the end of the project will have added $6.4 billion to the original cost estimate made in the early 1980s. That sum alone is more than half the difference between the original estimate and projected final cost. Following federal rules, the original cost estimate included no allowance or calculation for inflation.

Other key cost drivers (shown in current dollars) include:

1. Major growth in project scope and traffic maintenance added $2.7 billion to project costs. Some major costs that were not part of the 1982 concept include:
   - Rebuilding the Dewey Square Tunnels
   - Adding new interchanges at Logan Airport and Massachusetts Avenue
   - The use of more complex construction methods required for the Fort Point Channel Tunnel
   - The roofing of open-air tunnels in South and East Boston
   - Building of temporary ramps to maintain traffic flow during construction
2. Environmental compliance and mitigation increased project cost by $3 billion. Examples included:
   - Redesigning the Charles River Crossing
   - Disposing of material on Spectacle Island instead of in the waters of Boston Harbor to develop a public park

[2] David Luberoff and Alan Altschuler, *Mega-Project: A Political History of Boston's Multibillion Dollar Artery/Tunnel Project* (Cambridge, MA: John F. Kennedy School of Government, Harvard University, Rev. ed., April 1996)., VI-6 to VI-8. Such factors affect many other large projects as well, leading the authors to note in another study that dramatic cost escalation of the kind seen on the Big Dig is "not out of the ordinary for a major highway project." See Altschuler and Luberoff, *Megaprojects: The Changing Politics of Urban Public Investment* (Washington, D.C.: Brookings Institution, 2003), 116-117, citing the examples of Century Freeway and Woodrow Wilson Bridge.

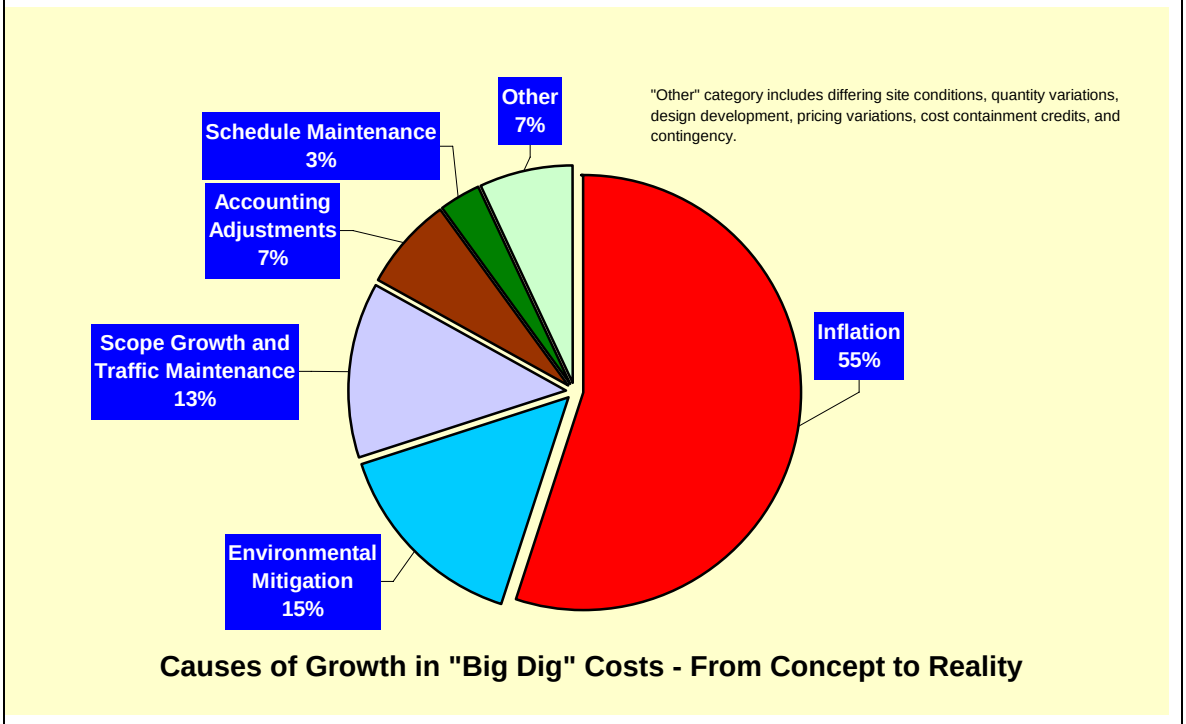
- Adding high-occupancy vehicle lanes to the Interstate 90 and 93 alignments

3. Accelerating the construction schedule cost some $600 million. In 1995, MHD decided to increase the pace of the project after B/PB reported that trends pointed to a serious slippage in its future schedule. Paying for more workers, more equipment, and more work shifts cost the project about $600 million. As a result, the project's completion date has slipped only nine months in 11 years.

4. Accounting adjustments added $1.2 billion, reflecting changes in government guidelines for allocating costs. For example, until 1999, MTA showed an insurance credit of up to $800 million as an offset to the overall project cost. In 2000, after several years of recognizing the credit, the U.S. Department of Transportation disallowed this offset, effectively adding $800 million to the project's price tag.

Figure 1 shows the relative contribution of these and other factors to the overall growth in project cost estimates:

Figure 1



Cost Estimating and Disclosure

The process of developing cost estimates on the Big Dig was necessarily evolutionary. It is not possible at the beginning of such a large, lengthy, and complex project to anticipate, with precision, all final design and program decisions that will be made by the state and other interested parties, as well as the extent and nature of unanticipated conditions that impact cost and

schedule. Nor is it possible to predict, with accuracy, the fluctuating bid climate and related market conditions that may exist throughout the life of a long project. As decisions were made and conditions evolved on the Big Dig, however, B/PB factored them into its cost assessments and kept the client fully informed, even in the face of strong political pressures.

In 1994, B/PB provided the governor and state officials with a total cost estimate of almost $14 billion to complete the project. MHD (and later MTA), under federal and state pressure to hold the line on project costs, was determined to maintain a total cost of $7.7 billion (about $10.4 billion counting inflation and third-party payments). It instructed B/PB to recommend scope reductions where possible and initiate cost containment and other efforts to offset any cost increases with cost savings. Then and later, the state transportation secretary's office forcefully reminded B/PB that responsibility for public discussion of project issues rested exclusively with the public officials managing the project, and that the contract prohibited B/PB from making any unauthorized statements to the public.

While advising that it would be very difficult to hold the line, B/PB worked aggressively with MHD and MTA to recommend and implement savings and cost containment measures necessary to meet the state's objectives. By 2000, however, project scope changes, contractor claims, rising construction costs, and changes in allowable accounting practices made it impossible for MTA to maintain its zero-budget-growth mandate. MTA's chairman announced a revised cost estimate of $12.2 billion (including inflation). The new figure proved highly controversial, and various public officials as well as the media moved quickly to assign responsibility for what was widely termed a "cost overrun."

The Inspector General of Massachusetts reported in 2001 that B/PB consistently "disclosed its bona-fide total cost projections to Big Dig officials" during the entire 1994-2001 period. The IG added, "B/PB insisted upon and, in fact, made full disclosure to local FHWA officials of each exclusion, deduction, and accounting assumption" used in the project's cost estimates.

Cost Control

The full story of spending on the Big Dig would record the creative and sustained efforts by project personnel to save money and maximize value to taxpayers. Effective cost control starts with systems and practices that facilitate accurate and timely cost reporting. B/PB developed a state-of-the-art Construction Information System to track individual contract tasks, change orders, and other data used in the assembly of project cost reports for MTA.

Combining this information with insights from years of engineering experience, B/PB developed and recommended innovative cost-containment concepts that have saved close to $1.7 billion over the life of the project with the assistance of MHD, MTA, and FHWA. They include:

1. Savings of $480 million from value engineering. B/PB gathered independent third-party experts from around the world to review designs, ask questions, and make suggestions. For example, the project saved $200 million from changes to the South Boston interchange alignment.

2. Savings of $750 million from cost-containment actions. For instance, B/PB helped save $60 million for disposing of 17 million cubic yards of excavated material.

3. Savings of $500 million from reducing the cost of insurance. An owner-controlled insurance program eliminated the need for the contractor or consultant to buy commercial insurance. In conjunction with the Big Dig's excellent safety record, this approach eliminated overlapping coverage and allows MTA to realize economies of scale.

Public officials must balance a variety of factors and have not always accepted B/PB's recommendations for cost control. Two examples:

- B/PB proposed a Purchase Street bypass that would have saved approximately 18 months and, conservatively, more than $100 million; concerns about effects on traffic and opposition from within the neighborhood led MTA to reject the proposal.
- The joint venture proposed not to restore the Dorchester Avenue bridge, which would have saved tens of millions of dollars. MTA reversed its original acceptance after the adjacent U.S. Postal Service regional headquarters objected.

Conclusion

Bechtel/Parsons Brinckerhoff is proud of its role in helping the Commonwealth of Massachusetts manage one of the largest, most complex, and technically challenging infrastructure projects in U.S. history. In the course of successfully meeting those challenges, and responding to a multitude of public concerns and interests, the project has changed in myriad ways over the past quarter century, delaying its completion and increasing its cost. Through innovative engineering and management, we helped the state control costs and schedule, saving taxpayers hundreds of millions of dollars and bringing benefits more quickly to Boston-area motorists and residents.

The economic benefits to the region during construction have been enormous, and will continue long into the future. The downtown Central Artery (I-93) is capable of carrying 245,000 or more vehicles a day comfortably, far more than the old artery and without its infamous traffic jams. It has cut the average trip through downtown Boston from 19.5 minutes to 2.8 minutes. In addition, the Ted Williams Tunnel can carry more than 90,000 vehicles a day. By cutting downtown traffic congestion, residents and businesses will enjoy benefits estimated at about $500 million a year. That figure is based on lower accident rates, less wasted fuel from engines idling in stalled traffic, and reduced late-delivery charges. The health benefits should also be substantial, starting with a 12 percent reduction in carbon monoxide levels.

The project will generate $7 billion in private investment and create tens of thousands of jobs, according to a Boston consulting firm.[3] Property values in downtown Boston are soaring as the Big Dig reconnects neighborhoods severed by the old elevated highway and improves the quality of urban life beyond the limited confines of the new expressway. Where the old elevated roadway once stood, residents will now enjoy open space and modest development. The project will create more than 260 acres of open space, including 30 acres where the existing Central Artery now stands, more than 100 acres at Spectacle Island in Boston Harbor (where project soils are capping an abandoned dump), and 40 more acres of new parks in and around downtown Boston. The Central Artery is the first step toward an exciting urban renaissance.

[3] For more on the study by Economic Development Research Group, Inc., see http://www.masspike.com/user-cgi/news.cgi?dbkey=201&type=Archived&src=newsarchive.