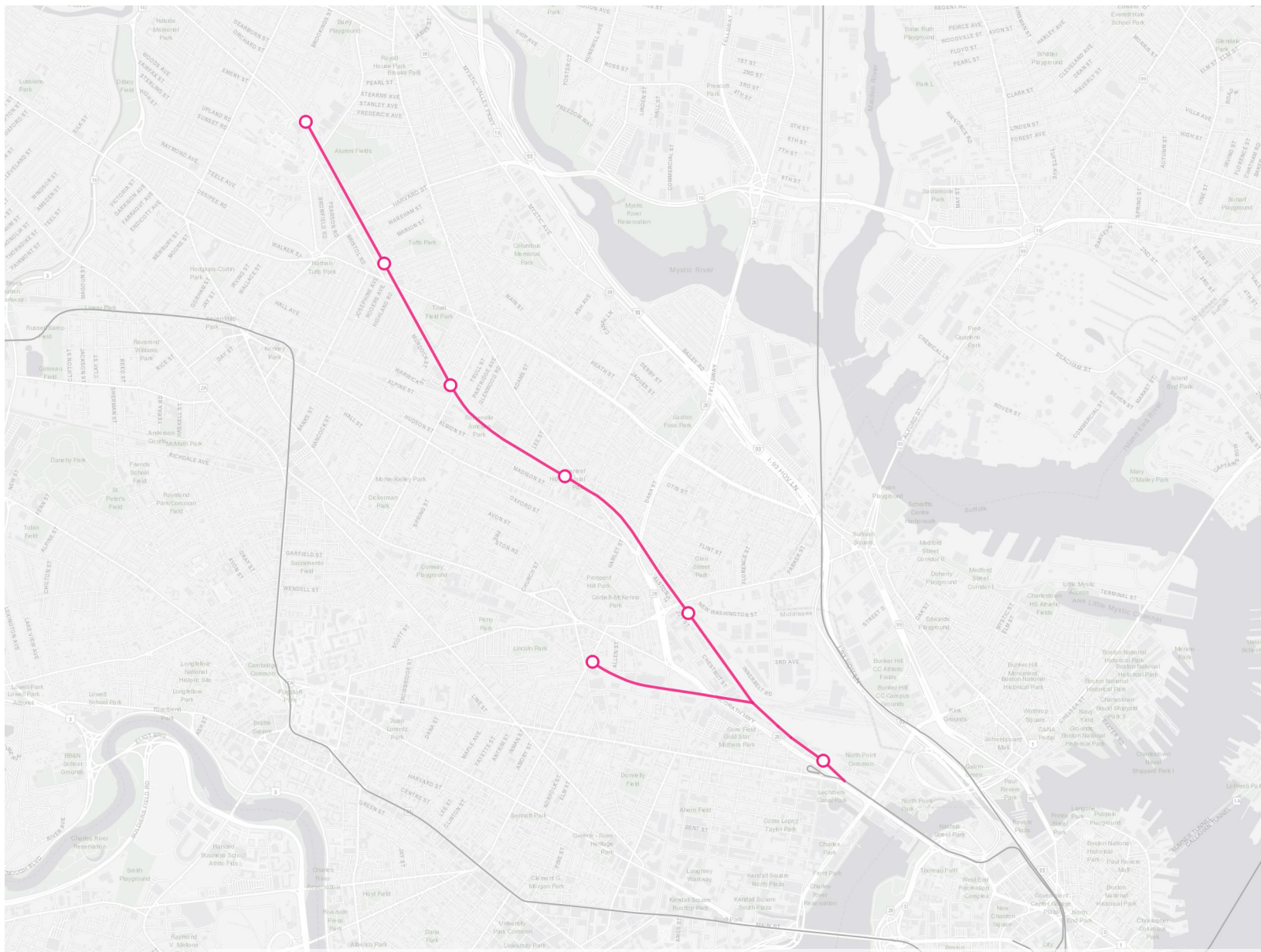

The Boston Case:
The Story of the Green Line Extension

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INTRODUCTION

The Issue of Infrastructure

The idea of creating a mass public works program in the United States to build useful infrastructure is a popular one in twenty-first-century politics. There was a widespread conversation on this topic during the stimulus debate of the early Obama administration. Subsequently, there have been various proposals for further federal spending on infrastructure, including state-level programs, the Trump Administration's much-mocked Infrastructure Week, and Alexandria Ocasio-Cortez's Green New Deal. In March 2021, the Biden Administration released the first part of its potentially $2 to $4 trillion infrastructure plan (Tankersley 2021).

This is not purely an American debate, either. The Trudeau cabinet has committed nearly C$200 billion in infrastructure spending in Canada, including, for example, helping fund a subway under Broadway in Vancouver (Wanek-Libman 2020). Within Europe, there is considerable spending on infrastructure as part of the coronavirus recovery program, even in countries that practiced fiscal austerity before the crisis, such as Germany (De Weck 2020). China likewise accelerated the pace of high-speed rail investment during the global financial

crisis of 2009 and its aftermath and is currently looking for major investments of comparable scale due to the economic impact of the COVID-19 pandemic (Burroughs 2020).

With such large amounts of money at stake—the $2 to $4 trillion figure proposed by Biden is about 10%-20% of the United States' annual economic output—it is critical to ensure the money is spent productively. The reason governments spend money on infrastructure rather than just giving people money as welfare is that infrastructure is a permanent investment. It is desirable to ensure that a fixed amount of money creates durable, permanent infrastructure that furthers a country's economic, social, and environmental goals.

Why We Study Rapid Transit

Building rapid transit is unusually valuable for governments, as subways, metros, and light rails operating at high frequencies generate economic value by permitting urban growth. Bunten (2017) argues that solely building more housing in congested, high-demand cities like New York and San Francisco carries a benefit of 1.4%. This finding counters Hsieh and Moretti's (2015) 13.5% benefit estimate. Bunten assumes a static transportation network since construction costs in those cities are so high; thus, more population equals greater congestion, which dampens the effect of development on the economy and introduces a negative traffic externality. In an environment where

transportation networks can grow with the city, the gains from development would be closer to those in Hsieh and Moretti; put in other words, the economic gains from being able to build dense urban transportation networks are likely to be about 10% US-wide.

These dense transportation networks have to be rapid transit–based. This is partly for environmental reasons—in a dense city, it's especially important to have low-pollution transportation. But it's also true in a future world where all cars may be electric. It is not possible to outdo the subway in capacity per amount of land consumed—and in a high-demand city, 12-lane freeways are prohibitively land-intensive. Hook (1994) argued that Japan focused on rail transportation in its largest cities because it had high land values in the postwar era and such strong property rights that widespread condemnation for land for freeways on the American model was not possible.

Thankfully, urban rapid transit is especially amenable to comparative research, because of its scale. Each line or phase is a large undertaking by itself: a single project routinely runs into the billions of dollars. This means that each project is itself the object of debate and media coverage. Relying on media reports and official government sources, we can get access to reliable data on the construction costs of a large majority of urban rapid transit lines in the world. We can likewise obtain costs for other megaprojects, such as high-speed rail.

In contrast, the vast majority of roadwork projects are small. A state's road money is typically split among many projects. Megaprojects for roads exist—for

example, the $1 billion Sepulveda Pass Improvements Project in Los Angeles—but only cover a small share of overall spending. The more typical investment in roads is a bypass here, a new interchange there, and a widening yonder, all repeated hundreds of times to produce hundreds of billions of dollars in roadway expansion per six-year transportation bill cycle. Headline costs for these projects may not be readily available, and when they are they often include too many unrelated extra side projects to be useful to compare.

The difference between roads and urban rail extends beyond data collection. We spoke with an engineer in Los Angeles who has worked on projects on both sides, and he explained to us that American road projects are essentially commodities (Interview A 2020). For example, a new public parking garage would be one of thousands of such structures built, which means that the costs and risks are well-known. It is also a simple project—just a parking garage. In contrast, an urban light rail or subway line, besides being one of dozens in the last generation rather than thousands, has many distinct parts: the civil structures, the tracks, the signaling system, the maintenance facility, the rolling stock. Far more prior planning is needed in the latter case, and the engineer told us that Los Angeles County's preference for outsourcing planning to private consultants with little public oversight works well for simple projects like parking but not for more complex ones like urban rail. To maximize the quality of rail investment, it is valuable to compare the efficiency of infrastructure for rail and not for higher-cost but institutionally simpler roads.

Why Costs Matter

We started the Transit Costs Project to understand how to reduce the costs of transit-infrastructure projects in the United States and other high-cost countries so that we can build more transit infrastructure. In much of the United States, there is political consensus behind the need to improve the state of public transportation. The reasons for this vary, but can include any of the following:

- A green desire to decarbonize the transportation sector, reduce air pollution, and undo the postwar trends of suburban sprawl and mass motorization.
- An association between the prosperity of a central city like New York or Boston and the strength of its subway system.
- Present-day limits of freeway-centric transportation such as traffic congestion and downtown parking scarcity.

This is by no means a national consensus. But it is a consensus in most of the largest cities, including those of the Northeast and the West Coast, as well as Chicago. But despite this consensus, there is little movement on the construction of expansive urban public transit. Even projects that enjoy wide political popularity move slowly, such as Second Avenue Subway in New York.

The problem is predominantly one of costs and construction difficulties. The Commonwealth of Massachusetts is eager to spend a few billion dollars improving the state of public transportation in and around Boston. There are a number of distinct rail investments in this range under construction or under planning with broad popularity, including the Green Line Extension (GLX), South Coast Rail (SCR), and upgrades to commuter rail facilities branded as Regional

Rail (RR). But as costs creep higher, timelines drag on, and promises aren't kept, as we will see in the Green Line Extension case, the public loses faith in transit agencies' ability to deliver high-quality infrastructure at a reasonable price.

This is not a unique problem to Boston. The problem of high costs is nationwide. According to our database (Transit Costs Project N.D.) of more than 600 projects in 58 countries, the United States is the sixth most expensive country in the world to build rapid-rail transit infrastructure. This is slightly misleading, however, because construction costs scale with the percentage of tunneled track. The five countries with greater average costs than the United States are building projects that are more than 80% tunneled. In the United States, on the other hand, only 37% of the total track length is tunneled (Image 1).

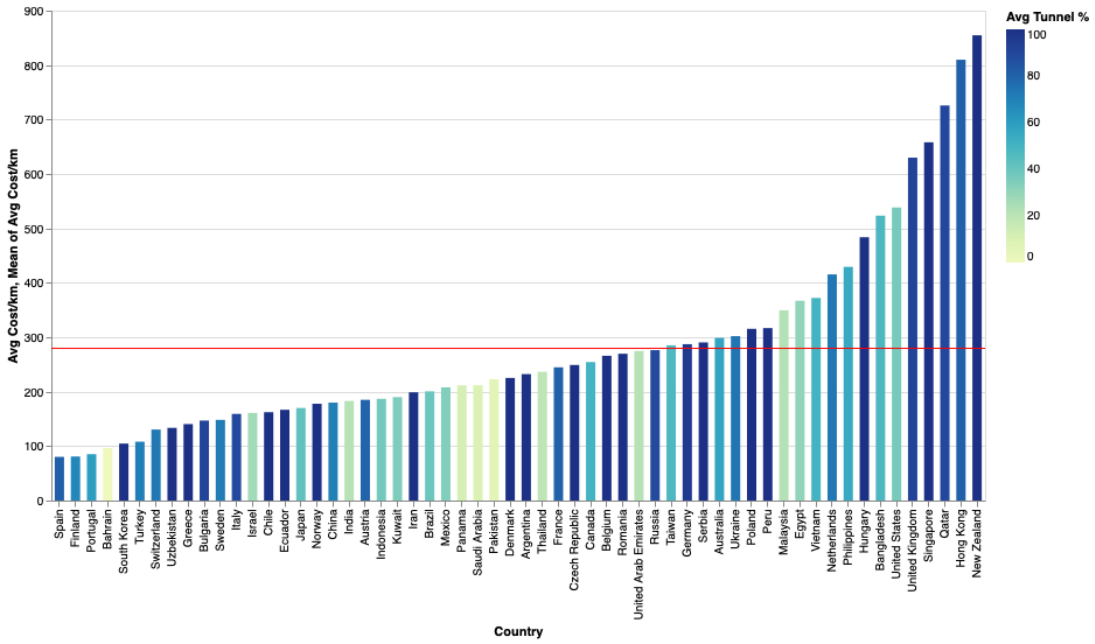

Image 1: Average Cost per Kilometer by Country.

Nonetheless, the bulk of American rail construction occurs in the context of broad local political support, and even then, long-term planning is not strong and the outcomes are poor. Therefore, it is valuable to understand what it is about the physical, institutional, and social situation of Massachusetts, New York, Illinois, or California that frustrates dreams of subway expansion.

Why the Green Line Extension?

Boston and its Green Line Extension (GLX) project form the first of six case studies that we are tackling in order to understand how one can build public transportation more efficiently and less expensively. When choosing cases, we looked for a number of different variables to avoid drawing general conclusions from sui generis examples. These included the following:

- For the first American case, we wanted to avoid New York. The reason is that while American costs are generally high, New York's are uniquely high, and therefore it is likely New York has an unusual set of failures not seen elsewhere in the country.
- Capital construction costs in Massachusetts have exploded over the last 40 years. While there hasn't been any expansion of the existing network since the 1980s, we see in Table 1 that even after adjusting for inflation, GLX is only 6% cheaper per kilometer than the Red Line extension to Alewife, which is entirely underground and has deep, cavernous stations. The Orange Line project may be a better comparison because the majority of the project was at-grade, with a short tunnel under the Charles; GLX, without any tunneling, is more than twice as expensive per kilometer.

Capital Expansion Project	Start	End	Length in KM	Tunnel Percentage	Stations	Cost	Real Cost	Cost/KM
Green Line Extension	2012	2021	7.6	0	7	2,289	2,289	301.2
Red Line Extension to Alewife	1978	1985	5.1	100%	4	574	1641.7	321.9
Orange Line Haymarket North	1966	1977	8.6	14%	6	180	1155.6	134.4

Table 1: Capital Expansion Projects in Massachusetts.

- We need excellent quantitative data in order to be able to see if there is a specific thing that went wrong. There is fairly uniform data reporting throughout the United States, but certain public-private partnerships like that of the Maryland Purple Line make it hard to disaggregate data.
- We need excellent qualitative data, that is, access to many different experts and practitioners who could help us understand what is going on. For idiosyncratic reasons, we have better access to such sources in Boston than in the rest of the United States, save New York and California.
- The history of GLX is dramatic: as we explain in more detail below, planning activities for GLX began in 2004 and continued through 2012. It underwent a cost explosion, and, in 2015, it was threatened with cancellation before it was rebooted with a new design, budget, and project delivery, leaving nearly $700 million of the old project's budget as a sunk cost. Each of these periods in GLX's story provide an opportunity to assess why costs diverged from expectations and how the MBTA salvaged GLX. Lessons learned here will provide avenues of inquiry as we pursue future cases.

SECTION 2

Project Timeline

The idea of extending grade-separated rapid transit from Boston north to Cambridge, Somerville, and Medford has been discussed since the 1920s. Studies in the 1940s, 1960s, 1970s, and 1980s all kept the idea alive, but the most recent iteration of the Green Line Extension (GLX) dates back to 1991 and the Central Artery/Tunnel Project highway project, also known as the Big Dig. In an effort to mitigate the negative air quality impacts of the Big Dig, Governor Michael Dukakis committed to several transit projects, including completing GLX by 2011, in order to comply with the Clean Air Act.[1]

While GLX has been in the pipeline for the last 30 years, changes in political administration, from Governor Michael Dukakis to Governors William Weld, Paul Cellucci, and Jane Swift, none of whom demonstrated any interest in expanding the existing transit network, have delayed its arrival. Without a champion in the governor's office pushing the project forward, other advocates took up its mantle. During Mitt Romney's tenure as governor, from 2003 to 2007, GLX did have the support of super-secretary Doug Foy, who, before joining the

[1] There is some controversy over the origins of this commitment and how much mitigation needed to be done because of the Big Dig; however, this is beyond the scope of this study. For more see Altshuler and Luberoff (2003) and former-Secretary of Transportation Fred Salvucci's testimony at the Green Line Extension Hearing (2011).

Romney administration, worked alongside the advocates pushing the Commonwealth to build GLX and honor its other transit commitments. In 2005, the second to last full year of Governor Romney's term, the Commonwealth, compelled by threat of legal action for being in noncompliance with the Clean Air Act, recommitted to opening up new Green Line service by December 31, 2014. In order to move the project along and avoid losing federal funding for roads and transit, the Massachusetts Bay Transportation Authority (MBTA) hired Vanesse Hangen Brustlin (VHB) to conduct an Alternatives Analysis to determine how best to serve the proposed corridor through Cambridge, Somerville, and Medford, which was published in 2005.

With the election of Deval Patrick as governor in 2006, the project did move forward—at least on paper. After completing the Alternatives Analysis and selecting a two-branch expansion of the Green Line as the preferred alternative, the Executive Office of Transportation & Public Works (renamed as the Massachusetts Department of Transportation (MassDOT) in 2009) took the lead on planning the project with support from VHB. Between 2007 and 2009, MassDOT convened a Green Line Extension Advisory Group, made up of representatives from civic groups, advocates, and appointees from Cambridge, Somerville, and Medford. The Advisory Group worked with the state to refine alignment, select stations, and, in the words of Chair Steven Woelfel, to "make the project work for everyone" (Executive Office of Transportation and Public Works 2007).

It was also in 2006 that the MBTA entered into a Settlement Agreement with the Boston Center for Living, a non-profit organization that provides services to people with disabilities, to make the MBTA's network accessible to all users. While the agreement only required adding elevators at existing stations in the network, such as Park Street and Downtown Crossing, those working on GLX decided to apply the agreement to their new stations as well, designing stations with redundant elevators, escalators, full enclosures, and fare arrays rather than a platform with a partial weather shelter, as was initially planned. In the "Beyond Lechmere Northwest Corridor Study" (2005), which contains the first conceptual cost estimate of GLX, it was estimated that these original no-frill stations, on average, would cost $535,000.

In 2007, the Executive Office of Transportation & Public Works and the MBTA submitted a New Starts Initiation Package to the Federal Transit Administration (FTA), which indicated that the Patrick administration intended to apply for federal funding to help pay for GLX. While the letter accompanying the initiation package stated that "the Commonwealth anticipates making an application to the FTA for entry into the Section 5309 New Starts process during calendar year 2008," the actual submittal occurred at the end of 2011 (Stern 2007).

In the intervening period between 2007 and the end of 2011, the primary project management responsibilities shifted from MassDOT to the MBTA. The MBTA hired a joint venture from HDR and Gilbane (HDR/Gilbane) to manage the

project, advance the design, and draft project delivery documents. VHB, a newly hired HDR/Gilbane team, and the MBTA moved the project through a number of regulatory hurdles, including a state-mandated Environmental Impact Report and an FTA-required Independent Risk Assessment.

As these steps were completed, a detailed project scope and cost estimate for GLX emerged.[2] In February of 2012, the plan for GLX was to thread 6.94 kilometers of track along two exclusive at-grade existing commuter rail rights-of-way, relocate an additional 6.44 kilometers of commuter rail track, widen the existing trench so that both the commuter rail and light rail tracks could comfortably fit, construct six new stations, relocate the existing Lechmere Station, erect four multi-span viaducts, reconstruct 11 bridges, build two new bridges, purchase power and train control systems, order 24 light-rail vehicles, install 21,000 square meters of retaining walls and noise walls, add a vehicle maintenance facility with test tracks and a transportation building, and acquire all of the necessary real estate to complete the project.[3] In 2012, the total project cost estimate, excluding finance charges, totaled $1.12 billion.

During the planning and design phase of a capital project, design and engineering advances from a general idea, such as an alignment along a specific corridor with a broad idea of station design and amenities, to a detailed final

[2] The first conceptual cost estimate dates back to at least the 2005 *Beyond Lechmere Northwest Corridor Study*.

[3] This project scope is compiled from multiple documents published by early 2011 rather than one document. The details differ from document to document and there is no reference to a Community Path.

design that specifies quantities of materials and systems details. At the earliest stages of design, such as conceptual design or 10% design, cost estimates include large contingencies to account for inevitable changes. As a design approaches 100%, the contingencies decline as the details and project scope are finalized. GLX's $1.12 billion estimate was based on an early stage, 10% design. Thus, many of the cost categories, such as stations, stops, terminals, intermodal and guideway and track element were assigned a 25% contingency to account for uncertainty. Additionally, the entire estimate had an additional unallocated contingency of 7%, which amounted to $80,474,000.

While the MBTA waited for the FTA to approve its submission to the New Starts grant program, the MBTA and its consultants bid out the first package of work for GLX. Massachusetts fully funded this initial contract, and it followed a traditional Design-Bid-Build procurement: HDR/Gilbane designed the project, and the MBTA and HDR/Gilbane team reviewed nine bids and selected Barletta Heavy Division. Their low bid was $12,989,300 to widen and reconstruct the Harvard and Medford Street railroad bridges, make roadway and drainage improvements, and demolish an MBTA-owned property in Cambridge that would serve as staging area for future construction. At the groundbreaking in December of 2012, United States Representative Michael Capuano, one of the few consistent GLX cheerleaders, underscored the urgency of getting GLX moving, saying, "We need to get as much of this project done and committed in an irrevocable way before [Governor Patrick] leaves office" (Jencks 2012). Capuano's desire to move

GLX out of the ethereal realm of studies and artistic renderings and into the tangible world of concrete and steel stemmed from his concern, based on previous administrations' disinterest in GLX, that the project could be delayed or cancelled at any moment.

In principle the first package of work affirmed Massachusetts' commitment to GLX with or without federal funding. In July of 2012, the FTA issued a Finding of No Significant Impact for GLX, which allowed GLX to be considered for a New Starts grant. In trying to expedite construction and keep GLX moving forward before the end of Governor Patrick's term in January of 2015, the HDR/Gilbane team proposed that the MBTA pursue a Construction Manager/General Contractor (CM/GC) project delivery strategy.[4] The agency opted for CM/GC because as HDR/Gilbane did more design work, it discovered unknowns and uncertainty, which is common, but also because, with a tight deadline to finalize a Full Funding Grant Agreement (FFGA) with the FTA and without all of the specifications identified in advance, incoming bids would be

[4] Project delivery is a critical element of transit-infrastructure projects. Throughout this case, we will discuss Design-Bid-Build, Design-Build, and CM/GC. While we suspect our readers have some idea of the different project delivery methods, it's worth stating that traditionally, North American transit projects are delivered using Design-Bid-Build. In a Design-Bid-Build project, a transit agency will hire a design and engineering consultant to develop a detailed plan for a project. The agency will then take those plans and solicit bids from contractors to construct them. The key part of Design-Bid-Build for our purposes is that the design team differs from the construction team. In a Design-Build project, an agency will hire a single entity, usually a joint venture, to design and build the project. While the agency will not hire a designer to develop final designs, the agency will hire a consultant to specify the project and make sure that the Design-Build bidders have enough information to bid on a project. CM/GC sits between Design-Bid-Build and Design-Build. Rather than buying a final design and then putting it out to bid, as in Design-Bid-Build, or entrusting a Design-Build entity to design a project with minimal oversight from the agency, CM/GC enables the design team and the Construction Manager/General Contractor to work together on designs iteratively and ensure that they are constructable and match the strengths of the construction team.

much higher in a Design-Build than in a CM/GC, which allows for joint exploration of the project and holds the winning bidder to a fixed markup rather than a fixed cost at the outset.

Under CM/GC, the MBTA contracted with a Program Manager/Construction Manager (PM/CM), the HDR/Gilbane team, to manage the design and construction of the project. Separately, the MBTA hired a design consultant, a joint venture between AECOM and HNTB, to advance the HDR/Gilbane design from the 30% level to final design and estimate all of the different elements needed for construction. Finally, the MBTA selected a Construction Manager/General Contractor (CM/GC), a joint venture between J.F. White, Kiewit, and Skanska, to build the project.[5] The CM/GC was brought on board prior to finalizing GLX's design so that the MBTA and its consultants could benefit from "preconstruction advice during the advanced preliminary and final design phases…concerning constructability, pricing, scheduling, staging, methods, efficiency, material procurement strategies, risk identification/management, and other areas related to the construction of the project" (Massachusetts Bay Transportation Authority 2012, p.1).[6] The MBTA and HDR/Gilbane argued that CM/GC's appeal stemmed from its ability to tap contractors' specific knowledge to establish a final contract price before

[5] The MBTA also hired an Owner's Representative and an Independent Cost Estimator.

[6] It is important to note that the design team was hired a full year before the general contractor. This means that as design advanced from 30% to 60%, there was no input from the general contractor as the design team committed to new plans and designs.

approving a final design. CM/GC is less rigidly sequential than Design-Bid-Build. When assessing these types of projects, the FTA is less concerned about a project being in the final design stage and more interested in seeing that the local financing is in place and that a list of standard items has been identified before approving an FFGA. We were told by someone with decades of experience with CM/GC that "items, such as bridges, retaining walls, and train control systems were left in preliminary design with the idea that the [CM/GC] would be able to use its means, methods, and materials that meet the specifications of the program and played to their expertise" (Interview B 2020). Thus, CM/GC could get to an FFGA more quickly than a standard Design-Bid-Build, because there was an understanding that the CM/GC's input would change the design, even if the overall objectives remained the same.

While the MBTA had never used CM/GC before GLX, its program management consultant, HDR/Gilbane, had experience with a variant of CM/GC, known as Construction Manager at Risk in vertical building projects. Based on its experience with this alternative project delivery method and the legacy of cost overruns and delays in transit projects, including the MBTA's recent Greenbush commuter rail project, HDR/Gilbane believed it could deliver an on time, on budget GLX by using CM/GC rather than Design-Bid-Build or Design-Build. CM/GC, while uncommon in Massachusetts transit construction, does have a track record in the United States. In an interview with the former head of capital construction at a transit agency on the West Coast who used CM/GC routinely, he

told us that, "When [CM/GC] works well, it is us [the agency and all of the contractors] against the project" (Interview C 2020). Design-Bid-Build, by contrast, he described as extremely confrontational and riven with bitterness because each contractor tries to protect its liability and offload risk onto the agency or subcontractors. Design-Build, on the other hand, is designed to keep the agency out of the design and construction work, which is a level of control that many agencies want to retain.

Without passing judgement on CM/GC, it is instructive to simply follow the reported FTA cost estimates for GLX as it worked its way through the FTA New Starts approval process.[7] According to the FTA's 2013 "Annual Report on Funding Recommendations: Fiscal Year 2014, Capital Investment Grant Program," GLX's total estimated project cost was $1.1158 billion. One year later, the FTA reported that the total project cost increased to $1.4288 billion. In 2015, the FTA approved GLX for a Full Funding Grant Agreement (FFGA), even though the total project cost had increased again: that year the MBTA reported that its projected cost was $1.992 billion, and that it sought $996 million from the FTA.[8] In the span of three years, GLX's projected costs increased by nearly a billion dollars, or 79%. Massachusetts Secretary of Transportation Richard Davey explained that changes to the project's scope, which now officially included a continuous pedestrian and bike path running alongside GLX, known as the

[7] We have also tracked other cost estimates that appeared in internal documents and the press.
[8] Each total project estimate excludes financing charges.

Community Path; greater costs associated with building a new viaduct connecting GLX to the one-hundred-year-old Lechmere viaduct; and a 30% contingency explained the cost increase. Even with these additions, Davey exuded confidence when he told the media that the project would be on time and under budget: "I'm thinking it will be more along the lines of $1.6 billion" (Metzger 2014).

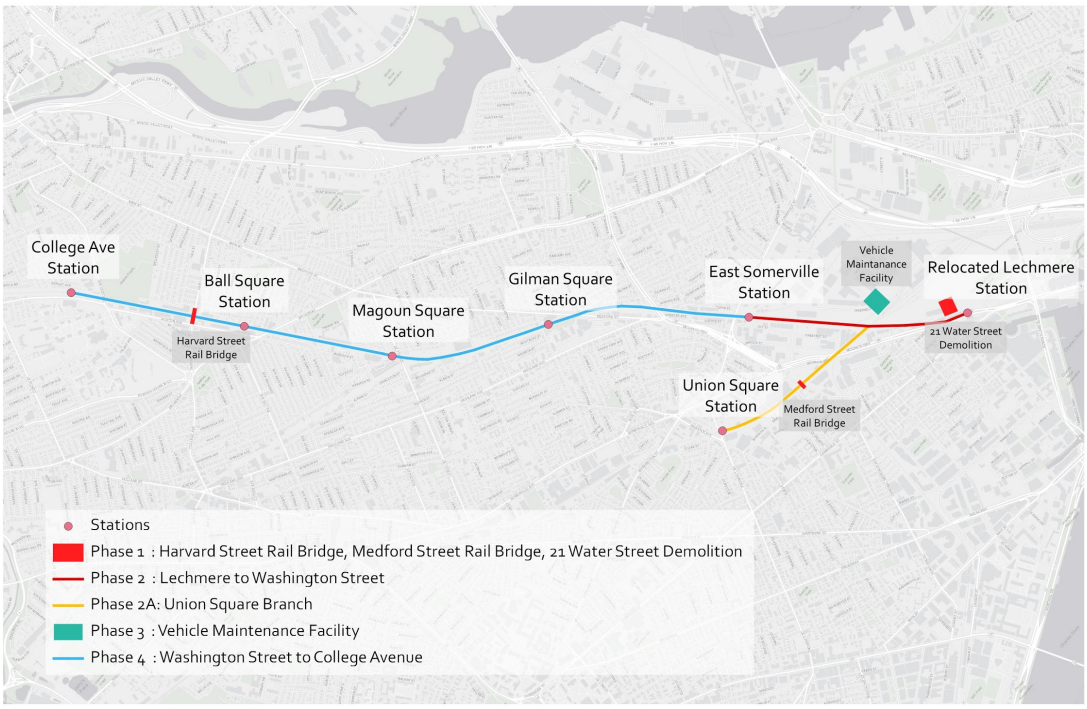

Image 2: GLX alignment and phase map adapted from Green Line Extension Project presentation 2/27/2012.

2015 should have been a moment of triumph for the GLX team. Even though Governor Patrick left office in January, that same month, the FTA agreed to contribute $996 million of the $1.992 billion project. While the project was still years from completion, this was, seemingly, the “irrevocable” commitment, to borrow a phrase from Representative Capuano, that assured GLX’s future.

During 2013 and 2014, however, it was clear that internal cost estimates from the PM/CM, HDR/Gilbane, and the CM/GC, the trio of J.F. White, Kiewit, and Skanska, were growing further apart, and that the five approved contracts were outpacing the projected costs underlying the FFGA and eating into the project's contingency. While negotiating the sixth GLX contract, in August of 2015, the CM/GC cost estimate for 100% design came in at more than double the projected amount. At this point, it appeared that GLX would likely require $3 billion to complete. Rather than pushing ahead and accepting the higher costs, the MBTA suspended negotiations with the CM/GC, and, in December of 2015, the newly created Financial Management and Control Board (FMCB) resolved that unless the project's costs could be reined in, it would cancel the project (Massachusetts Department of Transportation 2015).

Cancelling this version of GLX was an easy decision to make for several reasons. First, 2015 was an unusually challenging year for the MBTA. Beyond GLX's steady budget creep, multiple snowstorms paralyzed the system, which led to a litany of operating nightmares, namely major service disruptions—including day-long outages and severe delays. As this drama was unfolding, Beverly Scott, the MBTA's general manager, resigned. In the aftermath of the winter of 2015, the recently inaugurated Governor Charlie Baker convened a special panel to examine the agency's finances, operations, and general health. This added scrutiny brought to light a number of problems within the agency, such as a $7

billion backlog in State of Good Repair projects. In this environment, spending more money on GLX was untenable, despite nearly $700 million in sunk costs.

Second, observers of GLX believed the project could be value engineered to deliver the core promise of GLX for the initial price tag. As one agency insider told us, "We took the view that this project has to get done…[and] there was no doubt we could do better" (Interview D 2020). In 2016, in an effort to do better, the MBTA hired Weston & Sampson, an engineering firm based in Massachusetts to take a fresh look at the project and see where it could reduce costs without jeopardizing the goals of GLX. The interim team brought down costs by paring back the largest cost centers, namely stations, bridges, the vehicle maintenance facility, and the quantity of retaining walls required. By the close of 2016, the MBTA hired John Dalton, an experienced capital construction manager who had worked in the public and private sectors, and managed projects in Dubai and Chicago, to manage the GLX reboot and build a capital construction team within the agency. By 2018, there were 83 full-time employees working on GLX. During the first iteration of GLX, as a point of comparison, it was reported that only four to six full-time MBTA employees managed the multibillion-dollar project.

In 2017, GLX Constructors, a joint venture led by Fluor was selected to build GLX by December of 2021. This time, GLX will be delivered via a Design-Build contract. The final estimated project cost is $2.3 billion, but GLX Constructors received a $954 million construction contract with an additional $127.5 million in contingency controlled by the MBTA.

SECTION 3

Over the course of 45 interviews conducted over Zoom or the phone, hundreds of emails and text messages, and a review of relevant project-specific documents and media reports, we identified three core areas to help explain the trajectory of GLX.[9]

First, as GLX worked its way through the planning pipeline, it was passed back and forth from the MBTA to MassDOT and back to the MBTA. Staff at both agencies didn't always agree or appreciate input from the other. In particular, we were told in three separate interviews that the MBTA, the transit experts, disengaged from the project as MassDOT took a greater role in its planning. MBTA staffers bristled as MassDOT planners with no experience planning or operating a transit system took charge and established GLX's conceptual design and scope.

Despite objections from the MBTA's staff about MassDOT planners' involvement in GLX, the MBTA also lacked the expertise and experience to manage a multibillion-dollar subway or light rail project. From the 1960s to the 1980s, the MBTA developed its ability to plan and manage the construction of

[9] While some of the people we spoke to were willing to be on the record, many were adamantly opposed to being on the record for fear of losing out on future business or promotions. Since GLX is still in the process of being built, we decided to anonymize everyone we interviewed. However, we can say that we spoke with planners and staff at the MBTA and MassDOT, transit agency staff at other agencies, current and former FTA employees, consultants from firms who worked on and continue to work on GLX, members of the public working groups, advocates, former Secretaries of Transportation, elected officials, professional cost estimators, risk assessors, members of the Interim Project Management Team, academics, lawyers specializing in project delivery, and historians of Massachusetts' transit network.

large-scale capital construction projects. With the election of William Weld as governor in 1990 that changed. Weld came to power with a mandate to slash the Commonwealth's payroll by $1 billion and shed thousands of public employees. Under the supervision of his budget director Charlie Baker, Massachusetts cancelled transit expansion plans and contracted out functions that were previously done by the public sector. By 2005, on a day-to-day level, the MBTA no longer had the capacity to manage megaprojects like GLX because the most experienced construction managers had left the agency or retired decades earlier.

Even when planning and management responsibilities for GLX returned to the MBTA, MBTA staff committed the cardinal sin of expanding the budget and scope by calling for bigger and more expensive additions, such as the 8,733-square-meter vehicle maintenance facility, which was estimated to cost $195.5 million. As GLX design advanced and the project moved toward an FFGA, the MBTA hired HDR/Gilbane to manage the project. Internally there were only six MBTA staffers managing the project on a full-time basis, but HDR/Gilbane served as an extension of the MBTA and managed the project for the agency. Without the capacity to manage the project itself, the MBTA and MassDOT spent $212.99 million dollars on professional services to carry out this work. Even with the help of outside consultants, the agency struggled to stay on top of the volume of requests for information and requirements that accompanied a nearly $2 billion project. When GLX was redesigned and restarted, the MBTA hired more staff

internally to manage the project, a sea change from the previous version of the project.

Second, the managers of GLX did little to discipline the budget. Thus, ideas from stakeholders were added to the project scope or studied even if impractical. In the early stages of planning, public members insisted that the consultant, VHB, study the feasibility of tunneling GLX. While there is nothing wrong with this suggestion on its face, as minimizing property takings and nuisance mitigation are valid concerns, an informed professional committed to keeping costs down should have immediately explained that, as GLX is a light rail extension operating in an existing right-of-way with active commuter rail, building a tunnel would be costly and redundant. After months of study, this is exactly what the consultant found. In reading through the studies of GLX, we see that the design and cost estimates of stations also changed dramatically in the span of five years. In 2005, stations were designed to be unstaffed, unembellished, and easy to construct. By 2010, the concept for GLX's stations changed: "The design for each station is envisioned to provide a headhouse with automated fare lines, vending machines, an information booth, and restrooms. Entry to and exit from the platforms would be by elevators, escalators, and stairs" (Final Environmental Impact Report 2010).

Third, the more we spoke to people, the more we understood what was meant by the common refrain that "the politics of GLX are tricky" (Interview E, 2020). Because of the long delay of getting GLX built, the residents and elected

officials from Somerville, Medford, and Cambridge were tired of being told to wait. Adding insult to injury, GLX, as proposed in the Final Environmental Analysis, wasn't what had been promised in the "Beyond Lechmere" analysis. Instead of going to the Mystic Valley Parkway, GLX terminated at Tufts University/College Avenue, with the hope of extending it farther north in the future. The public aired its discontent at public meeting after public meeting. While people still supported GLX, they wanted more. The Community Path, a multi-use bicycle and pedestrian path, was a popular addition to GLX that was sold to the FTA as a station accessibility improvement, since none of the new stations along the Path would have automobile parking. In principle, the Path was a win-win: residents of Somerville got an extension of a grade-separated bicycle and pedestrian path that they had been trying to get built since at least 2001, and the MBTA and MassDOT built the community an amenity it wanted. In practice, the Community Path added costs to GLX and created tension between the Interim Project Management Team and the public as the Interim team tried to salvage GLX by scaling back the Path.

Even though we treat these three elements—project management and delivery, expensive design, and politics—as distinct subsections below, they overlap and interact in obvious ways.

Managing the Managers: Project Management and Delivery

From our interviews and a review of GLX-related documents, the combination of GLX's moving deadline (first 2011, then 2014, 2015, 2019, and, now, 2021), the perception that capital construction projects in Massachusetts needed new delivery mechanisms to keep them on time and on budget, and the desire to get FTA money led to the adoption of a poorly calibrated version of CM/GC rather than the preferred Design-Build or the more traditional Design-Bid-Build. Even though the court-mandated deadlines for GLX continued to slip and the Commonwealth had been granted the flexibility to swap projects in and out of its State Implementation Plans (SIP) to achieve clean air compliance, the December 2014 deadline for opening GLX created an urgent need to get the project built. Furthermore, December 2014 marked the final full month of Governor Patrick's second term in office, which, according to one senior person we interviewed meant that "figuring out how to get the FFGA done before 2014, meant not figuring out the project" (Interview D 2020).

Fundamentally, MBTA oversight was understaffed and stretched thin. Different experts that we interviewed who were involved with different aspects of the project put the number of in-house MBTA design review engineers at either five or six. With at most six people supervising the GLX project, little oversight was possible, leading to bottlenecks in signing off on orders and contracts. When GLX was finally rebooted in 2017, the MBTA addressed this deficiency by building a capital construction team with more than 100 MBTA staff. One senior person

involved with the current GLX project told us “I would rather be overstaffed than understaffed” (Interview F 2020).

In an interview with someone who has worked in multiple transit agencies in the United States and abroad, we were told that the benefits of internal staffing and capacity extend to the operating side of the agency, too. (Interview, 2017) contrasted London’s overstaffed, right-hand-does-not-talk-to-left schedule planning favorably with New York’s understaffed planning—and indeed, London’s unit operating costs (Transport for London 2016) are about two-thirds those of New York (Federal Transit Administration N.D.).

Hiring more in-house planners is a challenge. Public-sector wages for office workers are not competitive. A project manager for capital construction at the MBTA earns $106,000 a year in base salary; the equivalent in the private sector in Boston is $140,000 in transportation, and more in other industries such as tech. An official with the MBTA office workers’ union, the Local 453, gave a number of additional examples: a director of asset management at the MBTA earns $120,000 per year, although similar positions in New York and Chicago pay $180,000–200,000; a climate resilience specialist took a $20,000 pay cut to come work for the MBTA; the MBTA’s energy efficiency manager earns $85,000 and could make twice as much in the private sector (according to the official, the manager is only staying to put in the number of years required to earn a full pension when they retire).

The current GLX project has to some extent fixed this, by hiring outside consultants as well as in-house supervisors, generally at a competitive wage. However, the competitive pay is restricted to senior management. Junior planners still earn well below market rate. There is fiscally conservative reticence to expand government spending in the long run, especially in light of stories in the Boston Globe shaming workers who, through overtime, earn atypically large wages, leaving the impression that those wages are common for the public sector (Rocheleau 2020).

But regardless of what the current GLX project does, it is clear that the original GLX project did not attempt to expand the MBTA's institutional capacity to manage such a program. Decisions were made slowly, and there was much desire to limit risk. In contrast with transit agencies in Madrid or Istanbul, the MBTA was trying to limit its own risk. One contractor we spoke to complained of red tape that made contracting less flexible, saying "the T factor" or "the MTA factor" raised costs by about 10% (Interview G 2020). Despite this inflexibility, the MBTA wanted the contractor to take more risk, which the interview subject said just meant the contractor would find ways to mitigate their risk by charging extra if it ended up taking on additional costs.

This arrangement contrasts with Public-Private Partnership (PPP) structures in low-cost countries, which aim to minimize risk to the private contractor. Seoul, for example, built Line 9 cheaply using this type of partnership: rather than shifting the highest risk elements to the private sector, the PPP was

designed so that the private sector would do the low-risk parts of the line, such as the tracks and systems.

We see the results of diminished internal capacity at the MBTA throughout the project. Even though public meetings started back in 2004 and the outline of a plan emerged in 2005, no one at the agency took ownership of the project and shepherded it to completion. Instead, planning and design moved from department to department, knocking off one requirement at a time, such as the Alternatives Analysis and the state-mandated Environmental Impact Report (EIR). This meant that even after six years, the project hadn't moved out of the conceptual design stage.

In 2011, the MBTA hired HDR/Gilbane to draft a Design-Build procurement for GLX based on the design work VHB had done. As HDR/Gilbane did its due diligence, it realized there were still a number of unknowns, such as how to manage the elevated track work where the two branches of GLX converge by Lechmere Station, or how to address drainage problems in Somerville, and it determined that it would need to conduct its own studies rather than building on the existing work from VHB. With the agency short on time, spending more time studying the details of the project meant that it couldn't reasonably pursue its preferred Design-Build procurement, because it still didn't know what needed to be specified in the contract. Faced with uncertainty and a tight deadline, the MBTA and HDR/Gilbane latched on to the idea of building GLX using CM/GC, a project delivery mechanism that would allow them to hire a construction

manager to provide input on the design, schedule, and costs. Once design was finalized, the construction manager would shift to the role of general contractor and build the project. Thus, the MBTA could hire the CM/GC before final design, which under a Design-Bid-Build procurement could take several additional years.

CM/GC is an integrated planning, design, and construction method. In principle this means that as the design develops, the CM/GC provides input on constructability, value engineering, scheduling, and costs. Proponents of CM/GC argue that this collaboration between designers, PM/CM, and the CM/GC, all of whom contract with the agency separately, leads to CM/GC-vetted designs, predictable schedules, and greater cost certainty, all of which is meant to limit agency risk while allowing for the designers and CM/GC to innovate. As designs develop under CM/GC, say from 60% design to 90%, the CM/GC and an Independent Cost Estimator (ICE) provide cost estimates for the project based on a shared project scope and unit of quantities.

In the case of GLX, the MBTA selected a CM/GC project delivery, but made four critical errors drafting and implementing the agreement. Each of these flaws on their own created conflicts, but in combination they ramified through the project and brought it to collapse in 2015.

First, the MBTA failed to require open-book accounting, which allowed the CM/GC to price its work without meaningful oversight from the MBTA or the ICE. With limited ability to decompose CM/GC cost estimates, it was difficult to check the assumptions of the CM/GC's pricing.

Second, the MBTA hired the CM/GC too late—only after the design team had advanced the design from 30% to 60%. This sequencing meant that the CM/GC had zero input in this first phase of design work. In an interview with someone familiar with this stage of the project, we were told that the "whole philosophy [of CM/GC] is to get input from the contractor" (Interview H 2020). Thus, by starting the more advanced stages of design without CM/GC feedback, the design was not tailored to the CM/GC's strengths and there was less time for the CM/GC to innovate. As one source who has worked on dozens of CM/GC projects explained, "In CM/GC versus [Design-Bid-Build], the GC has the time to figure out a better way to build the mouse trap" (Interview G 2020).

Third, even though the MBTA had a CM/GC handbook that explained what to do when cost estimates from the CM/GC eclipsed the ICE's by more than 10%, the MBTA failed to manage these moments of conflict effectively until five contracts into the project. Rather than taking the final design and bidding it out via a Design-Bid-Build contract, it instead instructed the ICE and CM/GC to continue working on the bids until the CM/GC's estimate was within 110% of the ICE's estimate.[10]

[10] Two people we spoke with about CM/GC generally explained that 10% was too great a variance. The structure of CM/GC encourages the CM/GC to estimate its costs at the top end of the range. With a 10% window, a savvy CM/GC could underbid the initial procurement by claiming a too-good-to-be-true markup in order to secure the contract, and then make up the difference by maximizing the bid-on-work process. A smaller 5% window encourages the same behavior, but also incentivizes a more honest markup rate.

And fourth, the MBTA's management capacity, which was spread thin, limited its ability to intervene constructively when the PM/CM and CM/GC failed to agree on costs. The MBTA was also slow to respond to inquiries from the CM/GC and designers on issues like what systems would be installed in the stations, such as the CCTV or communications specifications. Without clear guidance from the agency, the CM/GC priced these elements higher than normal to avoid the risk of taking on greater costs when the agency finally made a decision.

* * *

Let's take a closer look at how the lack of open-book accounting and the inability to hold the CM/GC to the 110% of ICE estimates interacted with and led to much higher than anticipated costs. Thanks to the "BRG Look Back Study" (2015) prepared by the Berkeley Research Group, we have a clear accounting of the summaries of the cost estimates for some portions of the project, referred to as Interim Guaranteed Maximum Price (IGMP) and Guaranteed Maximum Price (GMP). In a CM/GC, it is traditional to prepare multiple IGMPs through the preconstruction and design phase so that the agency and its program manager can track price throughout the design process and revise budgets and total project cost estimates prior to finalizing design. In this section of the case study, we take a closer look at IGMP 3 and IGMP 4.

Once the design reaches the 100% phase, final design, the CM/GC submits its final estimate, and if it falls within 110% of the ICE's estimate, it becomes the GMP. The GMP, which takes effect before construction, serves as a cap on final costs. This provides certainty to the agency and shifts risk from the agency to the CM/GC. If things do not go according to plan, the CM/GC is supposed to take on the added costs. In the case of GLX, rather than having one GMP, the project was broken up into multiple contracts. One of the people we interviewed with extensive knowledge of project delivery in Massachusetts told us that this was another fatal flaw, because it made it difficult to hold the CM/GC accountable if its costs outpaced ICE estimates, and it allowed the CM/GC to recalibrate bids as construction progressed (Interview I, 2020). However, it is common for transit projects delivered with CM/GC to include multiple IGMPs. The broader issue with this version of CM/GC was the MBTA's implementation of its own CM/GC guidelines. The MBTA proved unwilling to push back on the CM/GC and bid out the final designs using Design-Bid-Build even if it meant slowing down the project. In fairness to the MBTA, at this phase of the project, little construction had been completed, and internal staff believed that, over time, the CM/GC estimates would become more reasonable.

The scope of IGMP 3 included relocating commuter rail track; making significant drainage improvements under the Washington Street bridge, including installing new pump stations and larger-diameter pipes; and drilling viaduct shafts. The estimate for this phase of work, which was the basis of the

FFGA, totaled $63 million. Disaggregated slightly, direct costs equaled $50.4 million, indirect costs $10 million, and the fee $2.6 million (Table 2).[11] At the 90% stage of design, the CM/GC estimated its direct costs of construction at $69,763,112. So before reaching final design, the CM/GC submitted a bid 10% greater than the FFGA estimate without accounting for indirect costs, estimated at 20% of direct costs in the FFGA, or the CM/GC's 4.25% fee. At first glance, this seems like an obvious red flag, especially given that it was significantly higher that the PM/CM's estimate, $34,695,229, and the ICE's estimate, $35,832,193. We were told, however, that despite the name, sometimes 90% design doesn't mean all facets of the design are 90% complete. In this particular phase of work, the drainage component was a bigger risk and required more monitoring and mitigation than initially anticipated, so perhaps the CM/GC was being excessively conservative.

FFGA Estimate GMP 3	
Direct Costs	$50,400,000
Indirect Costs	$10,000,000
Fee	$2,600,000
TOTAL	$63,000,000

Table 2: Reproduced from the "BRG Look Back Study."

Once design was finalized, all three (CM/GM, PM/CM, and ICE) submitted a new round of estimates (Table 3). This time, the PM/CM estimated $49,257,908

[11] Direct costs are the costs for building GLX, such as labor, materials, and subcontractors. Indirect costs are the costs required to manage the project, such as paying for office space, field supervision that ensures work matches blueprints, and contract administration.

for the direct costs plus the CM/GC's contractually agreed to 4.25% fee. While the PM/CM did raise its estimate, the CM/GC increased its estimate, too. At this stage of the bid submission cycle, also known as the drop, the CM/GC hit the high watermark of $101,865,073. Again, the two sides were as far apart as could be, which fueled discord between them. The ICE's estimate for the first drop grew to $70,753,609. Since the CM/GC estimate was greater than 110% of the ICE's, the MBTA asked the two sides to resubmit bids. Since the PM/CM and CM/GC were more than 100% apart from the PM/CM's estimate, and the relationship was already strained, the MBTA asked the PM/CM to stop participating in subsequent bids because the enmity between the two had become unproductive. One person we interviewed who participated in this stage of the project told us that "it was getting to the point where the [CM/GC] couldn't be in the same room as the [PM/CM] (Interview H 2020)." Another person we interviewed with knowledge of this round of drops told us that in order to carry out the estimate reconciliation process, the ICE met with the PM/CM and CM/GC separately in order to avoid confrontations.

	90% Design Direct Costs	100% Design #1 Direct Costs + Fees
PM/CM Estimate	$34,695,229	$49,257,908
ICE Estimate	$35,832,193	$70,753,609
CM/GC Estimate	$69,763,112	$101,865,073

Table 3: Reproduced from the "BRG Look Back Study."

After four more drops, which are detailed in Table 4, the two sides finally reconciled at a direct cost plus fee price of $88,704,746. When the indirect costs were added to this phase of work, the final contract came to $116,635,126. Looking back at the estimate included in the FFGA documentation, this final price was 85% greater than the estimated $63 million. Part of the problem with the initial estimate, we were told, is that once the CM/GC put the drainage work out to bid, even the lowest estimate from subcontractors put the total price tag of the work above the direct cost estimate prepared by the PM/CM. Additionally, the CM/GC's indirect costs, which we were told "were off the charts" (Interview J 2020), were so much higher than anticipated because the CM/GC wanted to bring on more staff in preparation for the next phase of work, GMP 4. By bringing on more staff now, it argued, it would be able to move more quickly through the next phases of the project, which would save money. Despite this line of reasoning, as we will see next, indirect costs broke even higher off of the charts in the next phase of work.

	100% Design #2 Direct Costs + Fees	100% Design #3 Direct Costs + Fees
PM/CM Estimate	N/A	N/A
ICE Estimate	$80,914,140	$79,744,911
CM/GC Estimate	$90,732,868	$84,940,606

	100% Design #4 Direct Costs + Fees	100% Design #5 Direct Costs + Fees
PM/CM Estimate	N/A	N/A
ICE Estimate	$83,411,507	$83,615,247
CM/GC Estimate	$88,954,854	$88,704,746

Indirect Costs	$27,930,380
FINAL CONTRACT	$116,635,126

Table 4: Reproduced from the "BRG Look Back Study."

While market conditions certainly played a role in the cost escalation, the lack of open-book accounting allowed the CM/GC to price work without the pressure of detailing its true costs and verifying that its profit was capped at 4.25%. Furthermore, since the PM/CM developed the initial cost estimates, it was defensive when both the CM/GC and the ICE ended up exceeding its estimates from the FFGA.[12] In a few instances, during the negotiations, we were told, the CM/GC did provide quotes from subcontractors showing that the cost of drainage elements for the project exceeded the PM/CM cost estimate. Open-book accounting would have clarified the CM/GC's assumptions, but the PM/CM needed to recognize that its estimates were also flawed, especially when faced

[12] We were told that CM/GC best practice only included the CM/GC and ICE estimates for this reason.

with concrete evidence. Without more transparency, the PM/CM assumed the problem was the CM/GC rather than its own estimates.

This issue of flawed cost estimation is a much deeper problem that relates to the process of how the federal government reimburses project costs and the rush to get an FFGA. Because costs incurred on a project do not qualify for reimbursement until the preliminary engineering stage, agencies want to spend as little money as possible to get to preliminary engineering. Thus, consultants work up cost estimates by taking historical data from "similar projects" and adding an escalation rate. This back-of-the-envelope approach is reasonable at the outset, as decision-makers think about pursuing different projects. But, as we were told by cost estimators, risk assessors, and project leaders from consultancies, the cost estimation of a project that has been selected from an Alternatives Analysis needs to be based on the specific conditions of the project, and that takes time and money that no one wants to spend. Where historical data is valuable, we were told, is in estimating quantities required to build a viaduct or drill a shaft. From there, however, a good estimator will take into account market prices for materials and labor rather than applying an escalation rate to old data. Whether or not this kind of upfront investment would mitigate uncertainty is hard to know, but it is certainly something to investigate across cases.

As worrisome as this round of drops was, things only deteriorated as the PM/CM, ICE, and CM/GC submitted estimates for the largest contract to date,

GMP 4, which included track work, retaining walls, three stations, viaduct work, and other key components of the overall program.

During GMP 4 negotiations, the MBTA put the project on hold to see if it was possible to salvage GLX within a budget it could afford. We were fortunate to access the cost estimates for GMP 4. We have reproduced a portion of the fourth and final drop in Table 5. Right away, we see that the CM/GC's estimate is more than double the FFGA estimate of $387,588,371 (Tables 5 and 6). In fact, the CM/GC, PM/CM, and ICE all exceeded the FFGA estimate by at least 60%. The CM/GC's total cost estimate was $869,214,343. The PM/CM estimate, unsurprisingly, was $250,000,000 less, at $619,009,838. The ICE's estimate, after learning some of the logic of the CM/GC from the last round of negotiations, ended up at $732,810,425. Since the CM/GC's estimate was more than 110% of the ICE's, this contract was never finalized. After looking more closely at the line items in this estimate, we see vast discrepancies lie in the indirect costs estimated by the CM/GC.

GMP 4 100% Design	CM/GC	PM/CM	ICE	DELTA CM/GC vs. ICE
DIRECT COSTS	$572,375,396	$460,714,878	$534,598,952	7.07%
Indirect Labor	$106,997,531	$54,327,123	$70,354,338	52.08%
Indirect Expenses	$118,405,819	$65,572,205	$84,199,356	40.63%
CM/GC Exposure Items	$36,000,000	$13,160,219	$13,783,013	161.19%
INDIRECT COSTS	$261,403,350	$133,059,547	$168,336,707	55.29%
FEES (fixed 4.25%)	$35,435,597	$25,235,413	$29,874,766	18.61%
TOTAL COSTS	$869,214,343	$619,009,838	$732,810,425	18.61%

Table 5: GMP 4 reproduced from authors' data.

In negotiating GMP 4, the CM/GC estimated its indirect costs at $261,403,350. When we looked at the cost estimate for GMP 4, instead of finding line items broken out with hourly wages and quantities of materials, we found lump sums at the top of section headers, such as Indirect Labor, with no labor hours to accompany line items like Field Supervision, Engineering, or Construction Manager Staff.

What we do know is that the CM/GC believed that it would require 1,792,301 hours to complete the construction work of GMP 4 and an additional 995,820 hours to manage it. In our interviews with cost estimators, they said that the ratio of direct hours to indirect hours on large projects usually falls within a range of 2.5 to 3, that is, for every 2.5 or 3 craft laborers on the job there is also 1 supervisor or manager. In this GMP, the CM/GC proposed a ratio of 1.8, or 30% more indirect labor hours. If this GMP had followed convention, the number of

indirect labor hours should have been closer to 700,000. Two people we interviewed who worked on the review of this phase of GLX specifically commented that there were two to three times more field supervisors on site than one would expect. The PM/CM, in stark contrast, estimated the indirect labor hours at 450,146 hours. The ICE, which had hewn closely to the CM/GC on the construction elements in the cost estimate, lost the thread when it concluded that GMP 4 would require 713,680 hours of indirect labor rather than the 995,820 proposed by the CM/GC.

When we compared the total indirect costs to the total direct costs, we found that the CM/GC's indirect costs equaled 46% of direct costs. This is an extraordinary proportion. Throughout our study of GLX, we have seen indirect costs estimated at 20% of direct costs, as we saw in the estimate for GMP 3. The actual indirect cost percentage of GMP 3's direct costs was 31%. In the FFGA estimate of GMP 4, the indirect costs estimate was 15% of $324,450,166 in direct costs. During negotiations for GMP 4, the ICE applied the same 31% from GMP 3, but still managed to miss the CM/GC's indirect costs estimate by $93 million. In our interviews with cost estimators, capital construction veterans familiar with CM/GC, and transportation design and engineering consultants, some of whom worked on GLX, we were told that indirect costs usually fall within the 15–20% range of direct costs, but that in dense environments, such as Somerville, it was likely that those percentages could creep up to 30% because of the restrictive

nature of work windows that limit the hours of construction and the difficulty of getting materials into and out of the construction site.

Clearly, CM/GC was not the silver bullet the MBTA believed it would be. Even after ten years of planning and multiple cost estimates, GLX still didn't have a reliable budget as of 2015. The dull work of figuring out the best way to build the Green Line Extension and staffing up the project appropriately was stymied by the pressure of staying ahead of different court-ordered mandates to build GLX and a lack of leadership from different political administrations, and a race to win an FFGA.

Contract Packages 1-7 for GLX

CM/GC IGMP	Status	CM/GC $	FFGA $	Variance	%
1	Awarded	$32,235,006	$22,528,833	$9,706,173	43.08%
2	Awarded	$18,042,718	$12,452,060	$5,590,658	44.90%
3	Awarded	$116,635,126	$62,667,946	$53,967,180	86.12%
4A	Awarded	$39,600,110	$44,688,166	($5,088,056)	-11.39%
4	Cancelled	N/A	$387,588,371	N/A	N/A
5	Cancelled	N/A	$391,816,547	N/A	N/A
6 + 7	Cancelled	N/A	$143,252,063	N/A	N/A

Table 6: Adapted from Green Line Extension Project FMCB Meeting 8/24/2015.

Big, Expensive Everything: Stations

As GLX was falling apart because of the inability of the CM/GC and ICE to find a workable price for GMP 4, the MBTA hired a new group of consultants to make sense of why GLX's budget exploded. Many of the people we interviewed explained that while the structural problems of CM/GC were the primary culprit,

these problems manifested themselves in overly ambitious plans that did not fall within the GLX's strict purview: to build amenity-packed stations, to re-engineer the existing trench to fit the commuter rail and GLX tracks, to integrate the multiuse pedestrian and bicycle Community Path, and to repair dilapidated overpasses and remedy decades-old drainage problems in Somerville.[13] Internally, the MBTA also pushed for a bigger vehicle maintenance facility and transportation building and personnel rooms in the new stations. One person we interviewed who was involved with the look back process and redesign of GLX explained that the project suffered from "pushing the yes button" (Interview K 2020): whenever a request was made to add an element, rather than managing the budget and sticking to the core goal of GLX, providing rapid transit service connecting Medford with Cambridge, the MBTA simply said yes.

The initial concept for GLX, as sketched out in the *Beyond Lechmere* Alternatives Analysis called for generic open-air stations with ramps to ensure ADA compliance. Through the planning process, these simple stations morphed into bespoke neighborhood icons with headhouses, redundant elevators, escalators, personnel rooms, fare arrays, larger footprints, and additional landscaping and street grading extending beyond the stations. One planner we interviewed who participated in the public forums on station design and the project admitted to us that "we could have been stronger at holding the line on

[13] According to Hopkins (2015), it would cost $5 billion to address Somerville's drainage problems.

some stuff" (Interview L, 2020). Another observer of GLX, who sympathized with the instinct to "push the yes button," explained, "Just because someone asks for something and it's a good idea doesn't mean it's possible" (Interview M, 2020). The Interim Project Management Team, which was responsible for getting GLX back within its initial budget, estimated the cost of GLX's seven stations at $409,500,000, more than 100 times more expensive than the estimate in *Beyond Lechmere*.

By looking at a specific station and the CM/GC's cost estimate, we see how costs scale with amenities and size. The proposed Union Square station, which we have included an image and cost estimate of below (Image 3; Table 7), was designed to occupy 1,387 square meters. The CM/GC estimated that it would cost $39,926,449, or $28,786/square meter, to build. For this specific station, the largest cost centers were steel, electrical systems, concrete, and site construction, which includes things like foundations, landscaping and irrigation, and site improvements.[14] In addition to these external elements, the station included a headhouse, bicycle storage, an entryway, a lobby, a concourse, two elevators, two escalators, two bathrooms, an employee lounge, fare vending, fare arrays, canopies, and mechanical rooms for all of the different systems. While elevators and escalators are expensive on their own—about $2 million in total in this instance—these amenities also require additional area dedicated to mechanical

[14] We include site improvements and landscaping because this station included two levels of exterior plazas with connecting ramps and outdoor seating and plantings.

rooms, which means more concrete, steel, and electrical work. The cost of electrical work, in particular, is stable over multiple footprints. Based on the estimate reproduced below for the three stations included in GMP 4, the range of costs for the electrical work is a tight band of $5,217–$5,597 per square meter. In other words, as station area increases, the costs of wiring and communications systems push total costs higher. The costs of elevators and escalators, on the other hand, relative to the overall station budget, reduces, so long as the design of bigger stations includes the same number of elevators and escalators as the smaller ones.

Image 3: Rendering of Proposed Union Square Station from 11/6/2014.

Union Square Station CM/GC Cost Estimate

Category	Estimate	% of Total
General Requirements	$1,773,593	4.44%
Site Construction	$5,341,805	13.38%
Concrete	$5,200,133	13.02%
Masonry	$1,126,719	2.82%
Metal	$8,446,352	21.15%
Wood and Plastics	$120,050	0.30%
Thermal and Moisture Control	$3,138,236	7.86%
Doors and Windows	$1,265,550	3.17%
Finishes	$1,973,009	4.94%
Specialties	$563,397	1.41%
Furnishings	$26,381	0.07%
Special Construction	$117,186	0.29%
Conveying Equipment	$2,061,867	5.16%
Mechanical	$1,508,253	3.78%
Electrical	$7,263,918	18.19%
Total	**$39,926,449**	**100.00%**

Table 7: Adapted from 100% GMP 4 8/14/2015.

As the Interim Project Management Team redesigned the project to get costs in line with the remaining budget, one of the first areas it attacked was the stations. The Interim design team slashed the estimated stations budget from $409.5 million to $121.2 million, or by 70%, by eliminating station amenities, namely iconic headhouses, personnel rooms, fare vending, escalators, and redundant elevators. By removing these items, the overall square footage of the seven stations shrunk by a staggering 9,959 square meters, or 91% of the previous plan. Based on our calculation of electrical work/square meter, we estimate that the bill for electrical work alone declined by more than $50 million.

After GLX was redesigned, stations returned to their spartan origins: today's stations will again be open air and have uniform materials, signage, and lighting so that there are both economies of scale when ordering materials and the same maintenance procedures at each station, which will reduce operating costs going forward (Image 4).

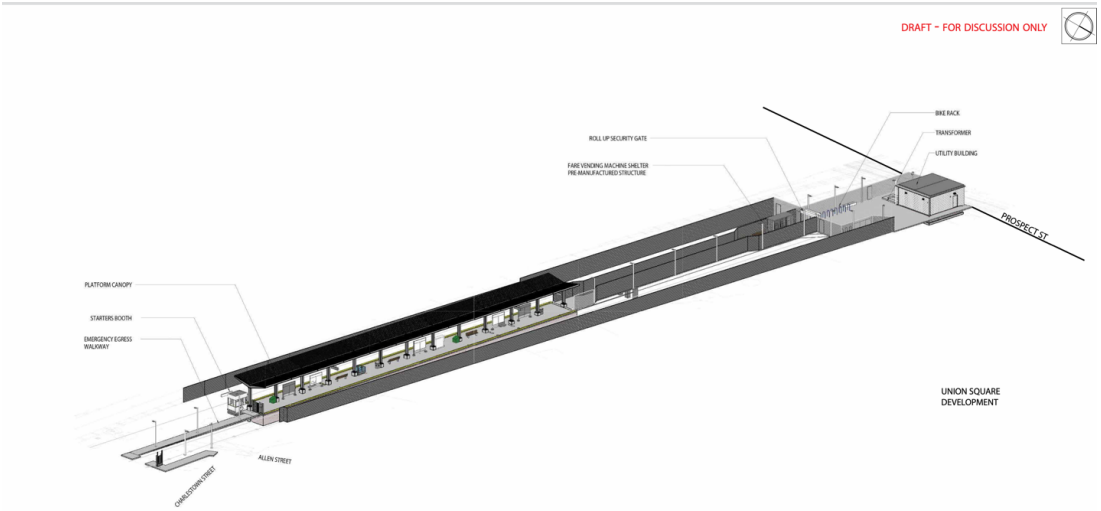

Image 4: Design as of December 2018 for Union Square Station. There are no elevators, escalators, personnel rooms, or fully enclosed public spaces.

Politics is the Project: The Community Path

Even though the Community Path, a three-kilometer shared bicycle and pedestrian path running alongside GLX's Medford branch from the proposed Lowell Street Station to the new Lechmere Station in Cambridge, was not included in the Green Line Extension's 2011 project scope, it had active supporters who fought for its inclusion by showing up to public meetings and lobbying elected officials. The Friends of the Community Path, an advocacy group

based in Somerville, met regularly from 2001 to 2004 and again from 2010 to 2018. The City of Somerville prepared feasibility studies of the path dating back to 2006 and sought federal funding for it on its own.

In October 2011, MassDOT and the MBTA hosted a hearing on GLX designed to give the public the opportunity to comment on the planning and analysis that had been conducted to date. 34 different speakers voiced their opinions about GLX. The comments tended to focus on GLX's delays, worries about the alignment being too short, and concerns about property and pollution. The specifics of each person's testimony often reflected their location; Brickbottom residents voiced noise concerns and Somerville residents were concerned with diesel train emissions. However, when it came to the Community Path, 13 different people, or 38% of all speakers, called for its addition to GLX.

Despite the Community Path's late entry into GLX's project scope, the MBTA argued that the Path improved access to stations. Once construction was completed, people living adjacent to the four stations intersecting with the Community Path would be able to safely access them on bicycle or foot. Since these stations lacked automobile parking, the Path was pitched as a real benefit to the overall project. How real those benefits were is up for debate—after all, why was station access only emerging as a problem to solve after the Environmental Assessment, which more or less locked in the mandatory project elements? While the project managers, designers, and others we interviewed about the Community Path defended its merits, they also acknowledged that

politics more than any technical consideration led to its adoption. Just as the scope of stations increased over time, the decision to enlarge the project scope and build the Community Path reflected a broader decision to appease the public and elected officials rather than maintain the project's scope and budget.

Integrating the Community Path with GLX was always an expensive proposition that would cost at least tens of millions of dollars—though in the grand scheme of GLX, it was a drop in the bucket. The primary issue was one of either cutting the Community Path into the same trench as GLX or hoisting it above the tracks (Image 5). Since GLX is in a constrained trench, the trench had to be widened to accommodate GLX's tracks; thus, folding in the Community Path and keeping it in the same right-of-way required additional excavation, retaining walls, and, in the proposed portion by Lechmere Station, its own viaduct rising above street level. Just as we saw with the cost estimates from GMP 4, mundane elements, such as concrete, metals, and electrical works drive costs. In the case of the Community Path's initial conceptual design and estimate from 2010, VHB projected that retaining walls and concrete would account for nearly 60% of the $22,329,000 budget. Since this was an early stage budget, it also included a 50% contingency to account for large changes to the plan. At this point in the design process, for instance, there were no plans to build a viaduct for the Community

Path. By the end of 2015, the cost estimate, according to Grove (2016) had ballooned to $100 million, or $33 million per kilometer.[15]

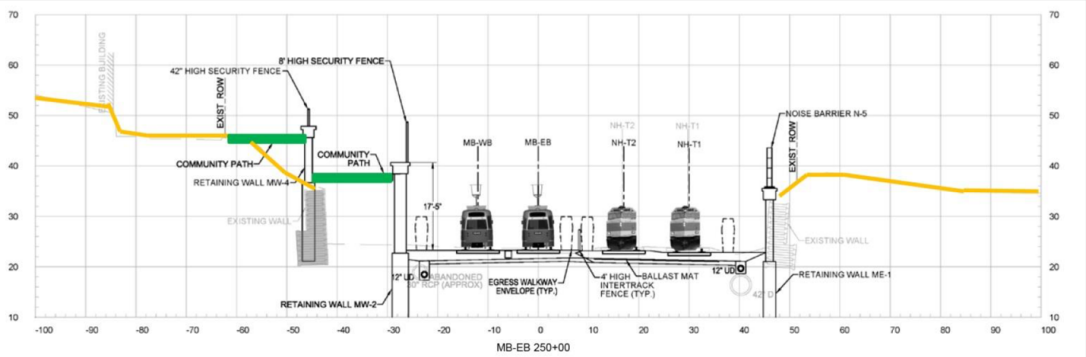

Image 5: Selection of a Community Path Section from the *Interim Project Management Team Report: Green Line Extension Project* (2016).

When the Interim team examined the Community Path, they approached it with the same ruthlessness as they had the stations and other elements in the project. One idea was to cut it from the project altogether. As noted throughout this section, however, the Community Path's popularity made it impossible to scrap, especially after it was included in the FFGA. Rather than eliminate the Path, the Interim team decided to realign it and trim it from 3,000 to 2,150 meters. By reducing the costliest section of it, the viaduct connecting it to Lechmere Station, the Interim team estimated that it would cost $20 million to complete. Even after MassDOT and the MBTA revealed that GLX's cost overruns jeopardized GLX's

[15] In our interviews, we received conflicting reports on the costs of the Community Path, but no one agreed that the Community Path added $100 million in costs. One designer we spoke with explained that if the Community Path had been built without GLX, perhaps it would cost $100 million, but in reality the extra retaining wall work extended existing retaining walls a few more feet rather than requiring new retaining walls. The viaduct portion in Lechmere, no matter what, was always going to be expensive.

realization, one attendee commented at a public meeting, “I think Somerville deserves a $100 million community path…. Somerville has sacrificed for everyone else’s transit convenience.” Another attendee stated their preference more plainly, “The path itself is at least as important to us as the Green Line” (Grove 2016). Today’s Community Path design includes the full three kilometers, but the new Design-Build team has stripped away amenities included in the previous design and narrowed it in places to keep costs low.

CONCLUSION

In our first case study, we have identified project management and delivery, design, and politics as three driving forces of costs. Understaffed agencies lacking experience with large capital construction projects struggle to manage consultants. In the aftermath of the first version of GLX, the MBTA committed to staffing up its capital construction team and streamlining its administrative processes so it can pay bills and respond to inquiries quickly. Once GLX is complete, it will be valuable to return to it and see what increasing internal capacity means in practice and if it made a difference. As of now, the projected construction costs are 43% of total project costs. By contrast, in Istanbul construction costs are often 75%–80% of total project costs.

We selected GLX as a case study because it is an extreme case with costs that defy global and even American averages for at-grade light-rail construction (Eno Center for Transportation N.D.). Rather than trying to understand the average case, which is also valuable, we studied GLX to identify specific areas of inquiry as key drivers of costs. Flyvbjerg (2006, p.13) highlights the value of extreme cases when he writes, “from both an understanding-oriented and an action-oriented perspective, it is often more important to clarify the deeper causes behind a given problem and its consequences than to describe the symptoms of the problem and how frequently they occur.”

As we complete more case studies, we will have a larger sample of project delivery mechanisms to compare and contrast. While GLX could be interpreted as a warning against CM/GC, we caution against that reading. Project delivery, like everything else, depends on the details. CM/GC as practiced in Massachusetts is different from CM/GC in Utah or Washington.

We are drawn to debates about alternative project delivery methods because it is an active area of policy debate in the United States. In New York, as part of a broader MTA transformation plan enacted in 2020, the agency must procure projects greater than $25 million via Design-Build (Slowey 2019). This concerns us because in Madrid, one of the lowest cost cities in the world to build subways, Metro de Madrid insists on Design-Bid-Build. We suspect the way they do Design-Bid-Build, using itemized lists leads to different outcomes than Design-Bid-Build with lump sum contracts, as it is practiced in New York. Our leading hypothesis, for now, is that internal capacity determines success or failure. The best designed project delivery can fail if implemented poorly. Conversely, Design-Bid-Build, Design-Build, Public-Private Partnerships, etc. can all work if the agency manages the project scope, budget, and relationships effectively. We have learned from international examples in Madrid, Istanbul, Milan, and Seoul that projects can be delivered at lower costs, relative to the United States, independent of delivery method.

Design, especially as it adds or subtracts materials and direct and indirect labor hours, has a significant impact on costs. In the case of GLX, we focused on

stations because they were dramatically descoped during the redesign process. Along the existing Green Line, we see simple stations that resemble bus shelters with zero charms or comfort along Commonwealth Avenue. The proposed Union Square Station that has now been scrapped drew no inspiration from these utilitarian stations. Instead, it was designed to include a showpiece headhouse, spanning nearly 1,400 square meters, two levels, plazas, redundant elevators, escalators, and other amenities. In New York, Los Angeles, and Toronto, we have seen costs for transit projects increase as station designs have become more elaborate. One capital construction executive explained rising costs as the product of a mixed mandate: "We aren't building transportation projects; we are building community" (Interview 2019). According to this executive, stations and the surrounding areas are no longer just places to wait for a train, but also places to meet up with friends and anchor neighborhood identity. As we shift our focus abroad, it will be interesting to see how station construction designs and methods in Madrid, Milan, Turin, and Istanbul differ from those in Massachusetts. These cities have figured out how to build uniform stations cheaply and quickly.

Disentangling the influence of politics on transit projects is challenging, but it doesn't mean we should ignore its impact. We see politics interacting with projects in two distinct ways: first, there are the blatant alignment and program decisions made to appease politicians, advocates, and detractors, like the Community Path. In Ethan Elkind's *Railtown* (2014), he describes the origins of the alignment of Los Angeles' first subway as a "political negotiation." Instead of

serving the densest corridor along Wilshire Boulevard, early plans were designed to build a coalition of the many by serving "the primary power centers in the county" (p.20).

Second, in an attempt to "do no harm," as Altshuler and Luberoff (2003) explain, projects are designed to avoid all controversy, real or perceived. As we saw with GLX, trying to satisfy Governor Patrick's desire to get an FFGA before he left office and win over members of the public who favored the community path or complained about noise impacts drove decision making. First, siting GLX in an existing right-of-way was the politically safe decision because it minimized property takings and obviated the need to clear a new right-of-way. Second, the current Design-Build contract limits the construction work that can be completed between 10PM and 7AM, requires bridge work on College Avenue to keep traffic flowing by only allowing temporary lane closures, and is careful to protect commuter rail service during construction. These well-intended overtures end up extending construction timelines and adding costs, because laborers are less productive when they have to spend the first hour of their shift setting things up and the last hour breaking things down to mask the fact that there is a major construction project underway.

In our interviews with consultants and cost estimators who have worked on transit projects across the country, they all agreed that productivity levels in the Northeast were especially low compared to other parts of the country. In Philip Plotch's *Last Subway* (2020, p.197), he recounts an interview with the

former head of capital construction at the Metropolitan Transportation Authority, who described the challenge of minimizing disruptions while constructing Phase One of the Second Avenue Subway as "'trying to ride a bike and change the tire at the same time.'"

By contrast, in Istanbul, transit construction projects run 24 hours a day, breaking down into three eight-hour shifts. It is no surprise that in the span of seven years, which is the expected duration of GLX construction, the Istanbul Metropolitan Municipality built M5, a 19.7-kilometer subway.

Since GLX is our first case, it informs what questions we will ask and which variables we will quantify in future cases so we can compare data more easily across countries and cities. We will continue to look closely at fine-grained cost data that allows us to compare the ratio of direct labor hours to indirect labor hours, the costs of stations per square meter, production rates, headcounts for key activities, and how indirect costs vary as a percentage of construction budgets.

In contrast with the failures in Boston, we hope that more cases will shed light on what success looks like. These should include very low-cost cities like Milan and Istanbul, but also medium-cost cities, which presumably have done some things right and other things wrong.

The ultimate goal of this research is to figure out how to bring down the costs of rail transit projects in the United States and other high-cost countries. We take a comparative approach to understand what drives costs, what reduces

them, and how to build transit projects more efficiently so we can build more of them. In future studies, we intend to look at how other cities contend with the three issues we've identified as cost drivers here: project management and delivery, design and engineering, and politics. Is this everything? Definitely not. But it's a start, and it should help us productively study more cities in the future.

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