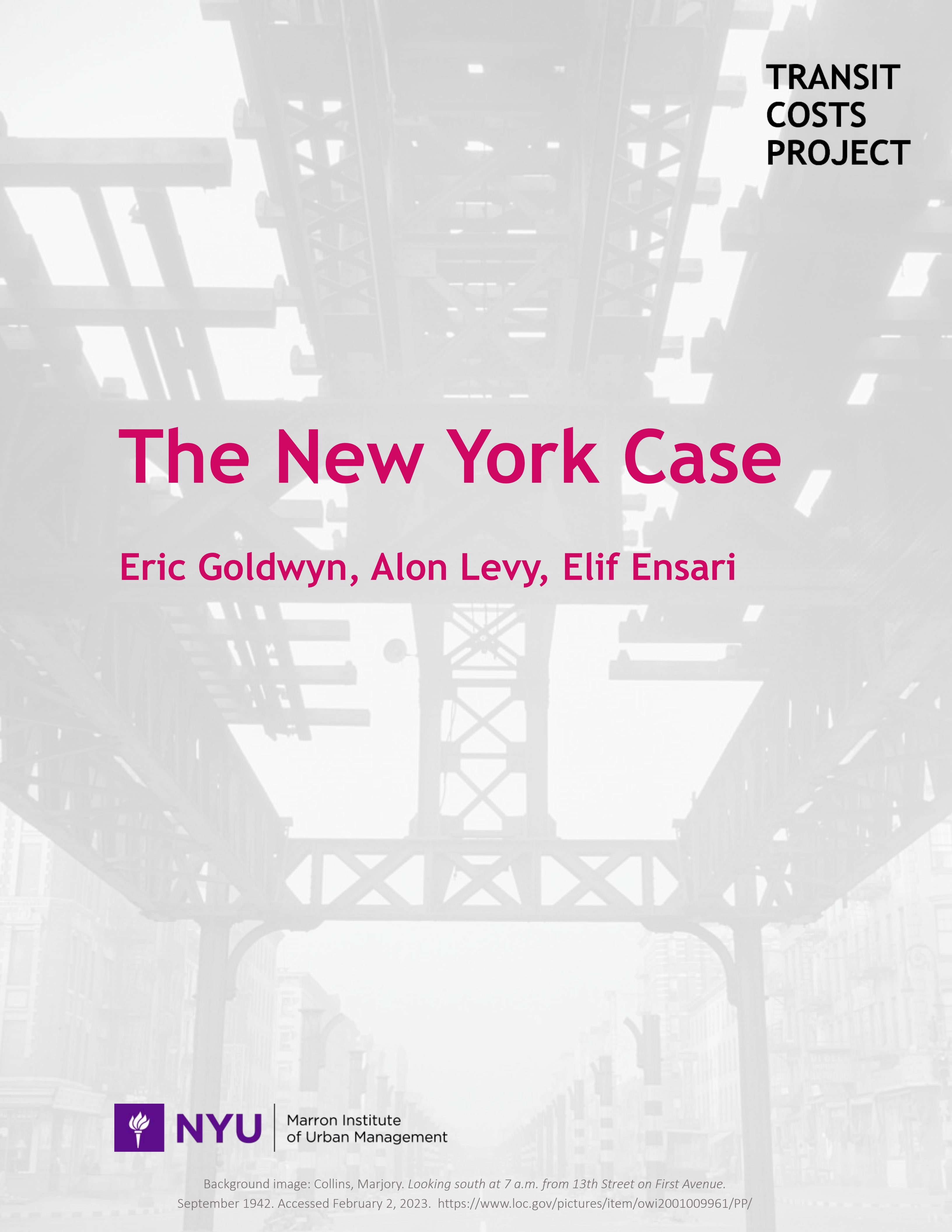

TRANSIT
COSTS
PROJECT

The New York Case

Eric Goldwyn, Alon Levy, Elif Ensari

NYU Marron Institute of Urban Management

Background image: Collins, Marjory. *Looking south at 7 a.m. from 13th Street on First Avenue.* September 1942. Accessed February 2, 2023. https://www.loc.gov/pictures/item/owi2001009961/PP/

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1 Introduction

New York has what is perhaps the world's largest subway capital program measured by total spending. The Metropolitan Transportation Authority's (MTA) five-year capital plan for 2020-2024 includes $54.8 billion in expansion, equipment purchase, facilities upgrade, and long-term renewal; of those, the subway's share is about $37 billion, the rest going mostly to commuter rail projects and to a small extent to buses (Metropolitan Transportation Authority 2019a, pp. 50 & 145). Because the capital program is so large, local media, academics, and think tanks have asked, is the region getting its money's worth for such a large program?

This case study examines the Second Avenue Subway, a project that spans multiple capital plans over the last 20 years and has been under planning since the 1920s. In 2005, as the present project was waiting for funding, longtime subway rider advocate Gene Russianoff said, "It's the most famous thing that's never been built in New York City" (Chan 2005). The full-length project was planned as a 13.7-kilometer line from 125th Street in Harlem to Hanover Square near the southern tip of Manhattan. Without the funding to complete the full line, the project was broken into four smaller, more affordable phases, of which only Phase 1 has been completed. Phase 2 is currently working its way through the engineering stage of the Federal Transit Administration's (FTA) New Starts program. Phase 1 is a 2.7 km three-station extension of the Broadway Line carrying the Q train along a preexisting tunnel from 57th Street and 7th Avenue to the 63rd Street and Lexington Avenue Station and continuing along a newly-built tunnel to 96th Street and Second Avenue on the Upper East Side.[1] There it connects to a preexisting

[1] We use 2.7 kilometers instead of 3.4 kilometers as Phase 1's measure because in our database we only count in-service portions of projects and exclude non-revenue components like tail tracks and maintenance facilities in our measurements. We do count those elements when detailing project scopes.

tunnel at 99th Street (Figure 1). This short extension opened for revenue service in 2017 and cost $4.6 billion in current year-of-expenditure dollars, or $5.3 billion in 2020 dollars.[2]

Figure 1. Phase 1 of the Second Avenue Subway map

According to our database of more than 900 rapid-rail transit projects from nearly 60 countries, Phase 1 of the Second Avenue Subway is the most expensive subway built in the world on a per-kilometer basis. This is about 10 times more expensive than the Italian and Swedish subways discussed in our other case studies, and more than 10 times as expensive as the Turkish subways we examined.[3]

[2] Costs are reported in year-of-expenditure dollars, but to convert to 2020 dollars, we use the midpoint of construction, 2011, and inflate $4.6 billion to 2020 dollars based on the Consumer Price Index.

[3] These are small sample size comparisons, and we recognize that no two projects are perfectly alike, some have automated trains, others have shorter platforms, and the geology in Istanbul varies greatly from New York's.

Focusing solely on costs, however, misses the enormous benefits produced by Phase 1. In the Final Environmental Impact Study (EIS) (2004), the MTA projected Phase 1 ridership to reach 202,000 riders per weekday, and for the full four-phase build out to serve 560,000 riders per weekday. This high ridership estimate is the result of serving one of the densest neighborhoods in the densest city in the country (New York City Planning n.d.). The projected cost per rider, about $23,000 in year-of-construction dollars and about $26,000 in 2020 dollars, compares favorably to ongoing subway and commuter rail tunnel projects in peer European cities, and far surpasses current American subway and light rail construction projects, such as Los Angeles Metro's Purple Line Extension Section 1, $83,000 per rider, and Sound Transit's Lynnwood Link, $50,000 per rider. Prior to the onset of the pandemic, Phase 1 ridership approached 200,000 weekday riders, it successfully alleviated congestion on the Lexington Avenue Line, reduced travel times, and increased adjacent property values (Metropolitan Transportation Authority 2022; Gupta et al. 2022).

New York's high construction costs, however, make it difficult to justify pursuing projects that produce fewer benefits than Phase 1. At roughly 200,000 projected riders per day, Phase 1 outperforms, on a per rider basis, less expensive projects with fewer riders, such as San Francisco's Central Subway extension or Washington Metropolitan Area Transit Authority's Silver Line extension. Phase 2 of the Second Avenue Subway, on the other hand, which is slated to run through East Harlem, also one of the densest urban neighborhoods in the United States with nearly 200,000 people per square kilometer in the areas surrounding the proposed stations, is currently estimated to cost $6.3 billion while serving 123,000 riders per day, producing a cost per rider ratio more than double Phase 1's (Federal Transit Administration 2022).

As the costs per rider metric increases with subsequent phases of the Second Avenue Subway, the benefit of building those extensions diminishes. This is too bad because until costs decline, the MTA will struggle to add new capacity at more than a few kilometers at a time. If New York were to build rail more affordably, it could reasonably plan and realize projects through less dense neighborhoods where demand is still high, such as the Interborough Express connecting Brooklyn and Queens or extending the W line from Lower Manhattan to Red Hook, Brooklyn, and even attempt to match the scale and vision of Paris's Grand Paris Express, a combination of rail projects that will add 200 kilometers and 68 stations via extensions of two existing lines and four new automated lines that will connect the inner suburbs. Grand Paris Express has seen its costs increase over time, but the current estimate is €36.1 billion in 2012 euros or $270 million/km in purchasing power parity (PPP)-adjusted 2020 dollars. With ridership expected to reach two million per day across the new services, Grand Paris Express will achieve a cost per rider comparable to Phase 1 (Vie publique 2020).

Our interest in the Second Avenue Subway, thus, stems from two overarching concerns. First, what is it about New York and more broadly the United States that makes it so expensive to build transit infrastructure? Second, if we are serious about getting people out of cars and accommodating population growth in New York and other American cities, we need to build extensive transit networks that connect major activity nodes, such as neighborhoods with housing, jobs, schools, and other amenities (Daganzo 2010). New York already has a developed transit network, but as more people move to the city and neighborhoods just beyond the reach of the subway, such as St. Albans and Maspeth in Queens, the transit system needs to expand.

Until the MTA can build transit for less, it will be difficult to add new infrastructure at a rate that keeps up with historical population growth trends. This is all the more critical as New York seeks to implement congestion pricing, upgrade its public realm, and reduce carbon emissions by 80% by 2050 (New York City Mayor's Office of Sustainability 2014).

Overall, the remainder of this report is divided into a narrative description in Section 2 detailing the history of the project from aborted past attempts to the successful Phase 1 opened in 2017, analysis in Section 3 based on our review of project-specific documents, media accounts, and more than 80 one-on-one and group interviews with contractors, manufacturers, risk assessors, lawyers, cost estimators, sub-contractors, designers, engineers, laborers, suppliers, current and former MTA executives and staff members, current and former transit agency executives and staff members outside of New York, local officials who interacted directly with the project, and advocates, and a brief conclusion in Section 4. After completing our research, we identified four broad areas that drove costs by adding schedule delay, calling for more expensive construction techniques, relying on costly inputs, and sacrificing productivity:

- Intergovernmental coordination and utilities
- Labor wages and staffing
- Procurement and risk
- Station design

Stepping back, however, and examining the New York case in the context of our other cases and broader research, we believe that uncertainty and a lack of leadership and funding certainty at the state, local, and agency level enables the MTA's costs to outstrip those found in Istanbul, Italy, and Stockholm.

The good news is that it is possible to reduce subway construction costs in New York; in our project overview, which includes our main findings and recommendations based on all of our cases, we go over more direct comparisons suggesting that if Phase 1 of the Second Avenue Subway had been planned, designed, managed, and constructed using similar methods to those found in our lower cost cases, its costs could have been reduced by as much as a factor of 8 to 12. Achieving these savings, however, is politically and administratively contentious.

2 Project Timeline

2.1 Early planning and navigating the FTA

The Second Avenue Subway had been planned many times before; in the 1970s, it was partly built, before the city's near bankruptcy forced construction to a halt. However, the project as built dates to 1988, when a group of MTA rail service planners recommended building a version of the Second Avenue Subway that would tie into the Broadway Line and extend from 63rd Street to 125th Street in Manhattan and continue to the Bronx (Figure 2) (Plotch 2021, pp. 124-132).[4]

The need for a Second Avenue Subway looked obvious: the parallel Lexington Avenue Line was the only north-south line on the East Side of Manhattan, and was crowded beyond capacity at rush hour (Metropolitan Transportation Authority 2001). But this group of planners recognized that no extension of this size had been completed since the opening of the 6th Avenue Line in 1940 (Regional Plan Association 2018; English 2021).[5] Just as earlier iterations of the Second Avenue Subway had struggled to be completed, it was uncertain that the agency could figure out how to both expand and maintain its aged and sprawling subway network simultaneously.

As the planners expressed skepticism about the agency's ability to build a Second Avenue Subway, David Gunn, the President of the New York City Transit Authority, fought for its inclusion in the MTA's Twenty Year Capital Needs

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[4] Since there have been multiple Second-Avenue-Subway plans since the 1920s, some plans extended into the Bronx and others left open the possibility of connecting to Brooklyn. What is constant, however, is the north-south service along Second Avenue in Manhattan.

[5] There were extensions and new stations completed after 1940, most importantly the 63rd Street Station that would later connect with Phase 1 of the Second Avenue Subway opened in 1989.

Assessment: 1992-2011.[6] With champions inside of the MTA fighting for the Second Avenue Subway and the city and state's fortunes improving after near bankruptcy in the 1970s, New York State, in 1991, allocated $22 million to update previous plans and designs from the 1960s and 1970s (Finder 1991). Even with this vote of confidence, there was a competition for resources as other operating agencies within the MTA, the Long Island Rail Road and Metro-North Railroad, also pursued large-scale megaprojects.

In 1995, the MTA began the $5.4 million Manhattan East Side Transit Alternatives Study (MESA). By not including Second Avenue Subway in the title of the study, the MTA wasn't bound to anything specific, which was important because few believed the Second Avenue Subway would arrive anytime soon. Norman Silverman, a Senior Director of Route and System Planning at New York City Transit (NYCT), described the likelihood of building a full-length Second Avenue Subway to The New York Times (Kennedy 1995) as on the "outer bounds" of possibility.

With little hope of building a full-length Second Avenue Subway, the MESA study analyzed four alternatives, none of which included a full-length Second Avenue Subway. Two of the four alternatives did include a semblance of it. One proposal called for the extension of the Broadway Line from 63rd Street to 125th Street along Second Avenue. This was similar to what the planners discussed back in the 1980s, but this time, the project would terminate in Manhattan rather than carry on to the Bronx. The second proposal included the Broadway Line extension and added a mostly at-grade light rail from 14th Street down to the Financial District. While no one would mistake this alternative for the full-length Second Avenue Subway—in fact both options were roundly criticized as being inadequate—the addition of the at-grade service was an attempt to serve the length of the island without breaking the bank (Personal Interview A 2022). One New York City Deputy Mayor believed that the final cost for the full-length Second Avenue Subway Cost could surpass $20 billion (Lueck 1999). The MESA study estimated the cost of the 63rd Street to 125th Street subway extension at $3.88 billion and the light rail build out at an additional $1.21 billion (MacFarquhar 1999; MESA 1999, p.2-27).[7]

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[6] The MTA comprises multiple operating agencies. While it's confusing to alternate between the New York City Transit Authority, later New York City Transit, and the MTA, we will mainly use MTA throughout this case. We will specifically reference New York City Transit and MTA Capital Construction when describing internal dynamics.

[7] MESA Cost estimates include hard costs and rolling stock, but exclude soft costs. Furthermore, these estimates were based on early-stage conceptual designs.

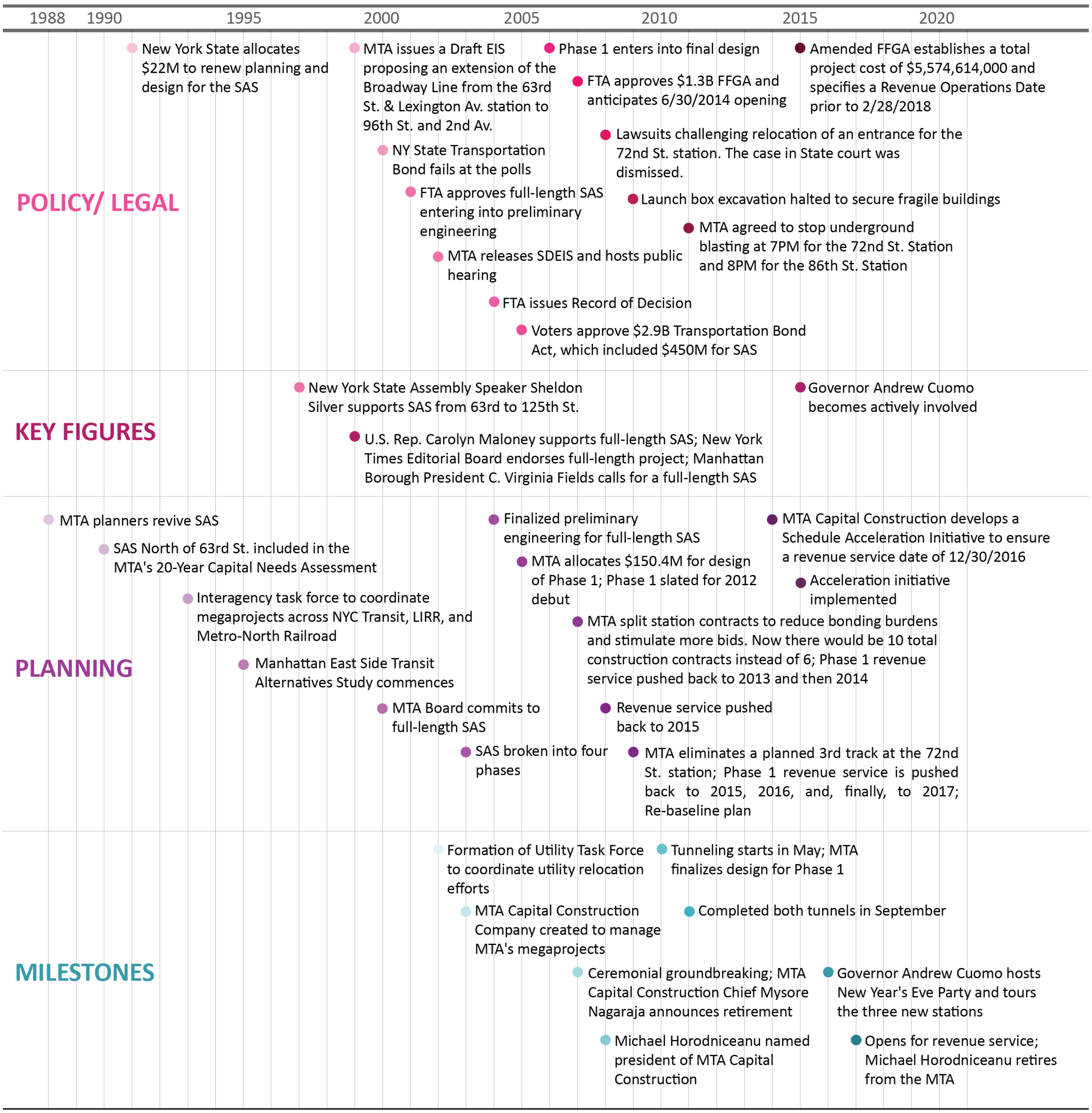

Figure 2. Phase 1 of the Second Avenue Subway timeline: Policy, key figures, planning and milestones

At the same time that these options were recommended, United States Representative Carolyn Maloney, Manhattan Borough President C. Virginia Fields, and *The New York Times* called for a full-length Second Avenue subway rather than a "stubway" north of 63rd Street. The primary sticking point for the MTA was money. The MTA couldn't build a full-length Second Avenue Subway, LaGuardia Airport subway extension, and Governor George Pataki's preferred project, East Side Access, without more money.[8] While the public supported a full-length subway, it didn't support higher fares to pay for it. Similarly, Governor Pataki was loath to raise taxes or reallocate money from the State's budget to finance a subway project in New York City, a city where he failed to win even 40% of the vote in either 1994 or 1998 (New York State Board of Elections 1994; New York State Board of Elections 1998).

In negotiating the New York State budget in 2000, State Assembly Speaker Sheldon Silver, who represented the Lower East Side, tipped the scales in favor of a full-length Second Avenue Subway. According to the New York Times (Perez-Pena 2000), Silver vowed "that there would be no state budget… until the Pataki administration commits to building the Second Avenue Subway the full length of Manhattan, and to a big increase in the state's contribution to the project's costs." Once Silver forcefully joined the side advocating for a full-length Second Avenue Subway, Governor Pataki capitulated. Within weeks of Silver's ultimatum, the governor and the legislative leaders agreed on a state budget, and capital programs for both the MTA and state highways. The MTA would allocate $1.05 billion in its 2000-2004 capital program for the Second Avenue Subway environmental review, design, and engineering in preparation of an Environmental Impact Statement (EIS) for the full-length route (Department of Transportation and Related Agencies 2002; Plotch 2021, 155).

Even with this concession from the Governor, the MTA still needed billions of dollars to build a full-length Second Avenue Subway. Over the course of 2001 and 2002, the MTA hired DMJM-Harris and Arup for $187 million to complete preliminary and final engineering and design documents (Lee 2002).[9] Now that the MTA had decided a full-length Second Avenue Subway was its preferred option for Manhattan's East Side, it released a Supplemental Draft Environmental Impact Statement that outlined a 16-station 13.7-kilometer project from 125th Street to Hanover Square that would cost $16.8 billion, or $19 billion in 2020 dollars, and be completed by 2020 (MTA New York City Transit 2001; Federal Transit Administration 2002; Bennett 2008).[10]

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[8] There was also the procedural issue of not having studied a full-length Second Avenue Subway. The MTA would have to file a Supplemental Draft Environmental Impact Statement that considered this alternative.

[9] DMJM+Harris later became AECOM. The joint venture would later have an option picked up by the MTA to provide construction phase support once construction began.

[10] The cost estimate is in year-of-expenditure dollars, but to convert to 2020 dollars, we use the midpoint of construction, 2012, and inflate $16.8 billion to 2020 dollars based on the Consumer Price Index. The project scope includes 16 new stations and a renovated 63rd Street Station to tie into the existing Broadway line.

With the contours of the project settled, the MTA moved into preliminary engineering and finalizing its EIS so that it could tender construction contracts in 2004. The only roadblock, at this point, was money. The MTA still needed to cobble together funding from state, local, and federal sources to proceed.

The Federal Transit Authority's (FTA) New Starts program is the main federal program to fund transit-infrastructure projects. In order to qualify for a Full-Funding Grant Agreement (FFGA), applicants, usually a transit agency, submit projects that have passed through an Alternatives Analysis, Preliminary Engineering, and Final Design. Along the way, the FTA judges submissions and approves projects to move through the project-development process based on measures of mobility improvements, environmental benefits, operating efficiencies, cost effectiveness, land use, and other factors (Federal Transit Administration N.D.).

In 2002, while the full-length Second Avenue Subway project was still in the Preliminary Engineering phase, the MTA's proposed grant request from the FTA was for $8,385,000,000, 50% of the projected total. While the FTA recommended funding the project, the MTA's request was nearly four times greater than any of the almost 40 requests from project sponsors still in the preliminary engineering phase of development.[11]

During fiscal year 2003, the FTA called for funding slightly less than $1.2 billion for 34 projects (Figure 3).[12] If we assume that a full length Second Avenue Subway would be in construction from 2004 through 2020, the FTA would have to allocate close to $500 million per year, on average, for just the Second Avenue Subway. The project's core benefit, alleviating congestion on the Lexington Avenue Line, was not a factor the FTA considered in its assessment. While the overall project rating was ranked medium-high, it scored "low" on the cost-effectiveness measure, which was based on projected new riders net of riders diverted from the Lexington Avenue Line and other mass transit lines (Federal Transit Administration 2002).

The MTA made two adjustments to combat these challenges on its way to securing an FFGA in 2007. First, the MTA lobbied the FTA to alter its cost-effectiveness metric to include the benefits of mitigating crowding on existing lines. Second, the MTA broke up the project into four smaller phases to reduce the size of the initial request to the FTA (Plotch 2021, pp. 172-175). The proposed Second Avenue Subway Phase 1 project would tie into the existing Broadway Line and run from 63rd Street and Lexington Avenue to 96th Street and 2nd Avenue. Its estimated cost

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[11] The MTA's East Side Access request was the next closest request at $2,175,000,000. Neither MTA request was representative of the scale of funding requests. Of those nearly 40 requests, only three of them were over $1 billion, with 13 more falling into a range between $200 million and $500 million, and 18 requesting less than $200 million.

[12] The federal government's fiscal year runs from October 1st through September 30th.

was $3.883 billion, excluding financing, and the MTA sought $1.3 billion from the FTA (Neuman 2007; Urban Engineers 2007a).[13]

These changes paid dividends. According to a revised 2007 Phase 1 assessment by the FTA, the FTA ranked the overall project "high" and amended its cost-effectiveness rating from "low" to "medium-high." The Cost per New Rider was still high, $170.32, but the newly included Cost per Hour of Transportation System User Benefit measure was low, $14.16 (Federal Transit Administration 2007).[14]

Even though the MTA published its Final Environmental Impact Statement and received a Record of Decision in 2004, the project remained in limbo because it was still uncertain how the MTA would pay for it. The FTA had not committed to an FFGA and the State of New York was unwilling to ratify the MTA's requested 2005-2009 capital program, which called for $27.8 billion with $1.4 billion for Phase 1. The State, instead, approved a $21.1 billion capital plan with $2.4 billion to be spread across East Side Access, Second Avenue Subway, and a rail link between Lower Manhattan and JFK airport (Chan 2005; Metropolitan Transportation Authority 2006). The MTA pressed forward under these challenging circumstances, partially of its own making, recognizing that securing the funds to build Phase 1 would depend upon debt and shifting around other pools of money.

Despite these less than favorable conditions, the MTA's funding picture did become clearer in 2005, 2006, and 2007. It didn't receive the $1.4 billion infusion it had hoped for from the State, but, in November of 2005, after the State had approved the smaller capital plan, New Yorkers voted for a $2.9 billion Transportation Bond Act that funneled $450 million to Phase 1 (Nobbe and Berechman 2013). Now that the MTA's local contribution to the project was firmer, the FTA allowed the project to advance into Final Design.[15] In 2007, three years after the MTA submitted its EIS and received a Record of Decision from the FTA, the FTA announced it would provide $1.35 billion to support Second Avenue Subway Phase 1 construction. Even with the FTA's $1.35 billion commitment, the three-year gap between the Record of Decision and the FFGA meant that the MTA had to push back the opening date of the project to 2014 and escalate its cost projections.

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[13] Ironically, Phase 1 of the Second Avenue is even stubbier than the "stubway" from the MESA study.

[14] Compared to the other projects in Final Design during Fiscal Year 2008, Second Avenue Subway Phase 1 had the highest Cost per New Rider and the lowest Cost per Hour of Transportation System User Benefit.

[15] In one interview, a former senior official told us that many within the agency expected the bond act to fail, which would have ended any chance of building the Second Avenue Subway (Personal Interview B 2022).

Figure 3. FTA grant requests, Fiscal Year 2003

2.2 The contracts

Second Avenue Subway's construction costs eventually amounted to $3.16 billion across 10 construction contracts and an additional $656 million over two design and engineering and construction management contracts (Table 1).

This was not intended from the start. In 2007, when the FTA and MTA agreed on the $1.35 billion FFGA with a revenue service date of June 30, 2014, the Phase 1 project scope included 2.7 kilometers of subway from 63rd Street to 96th Street, tail tracks for train storage, three new stations, a renovation of the 63rd Street Station, track and signal power systems, and 68 new rail cars (Figure 4). The initial breakdown of construction contracts included six packages: Tunneling, 96th Street Station, 63rd Street Station, 72nd Street Station, 86th Street Station, and Systems (Urban Engineers 2007a). In this iteration of the project scope, the 72nd Street Station was designed to have three tracks, and 86th Street and 96th Street were planned as two-track stations with island platforms.

With these details in place and funding more secure, the MTA moved forward with two contracts. The first contract, the first of six proposed construction contracts, was a Tunnel Boring Machine (TBM) Tunnels contract that included a launch box for the TBM, twin-bore tunnels and two vertical shafts for station construction at 69th and 72nd Streets. The $337 million 40-month contract was awarded to S3 Tunnel Constructors (S3). The joint venture was made up of Schiavone Construction, J.F. Shea, and Skanska (Metropolitan Transportation Authority 2011). In addition to the winning bid, the MTA received only one additional $495 million bid. Both bids exceeded the MTA's $290 million cost estimate (Urban Engineers 2007b; Rosenthal 2017).[16] The second contract was an $80.9 million Consultant Construction Management (CCM) contract with PB Americas to provide 91 months of construction management services, which include managing construction activities, coordinating between contractors and agencies, and performing inspections and documenting non-conformances (Urban Engineers 2007c).[17]

[16] Clearly only receiving two bids is not ideal. When we looked at other transit tunnel projects in the US from around 2007, we found that in 2004 Sound Transit also received only two bids for a 1.6-km tunnel. The winning bid was almost 20% greater than Sound Transit's estimate (Lindbloom 2004). In 2005, the winning bid for the North Shore Connector Light Rail tunnel in Pittsburgh was 25% greater than the estimate (Born 2012).

[17] PB Americas became WSP.

Table 1. Phase 1 of the contracts, proposed and actual budgets and timelines

	CONTRACT				PROPOSED		ACTUAL			INCREASE	
	Date	Contractor	Work	Bids	Duration	Cost	Completion	Duration	Cost	Duration	Cost
TUNNELS	3/20/2007	S3 Tunnel Constructors JV	TBM Tunneling	2	40 months	$ 337 million	3/30/2012	60 months	$ 378 million	50%	12%
96th STREET STATION	5/28/2009	E.E. Cruz/Tully Construction	Heavy Civil/Structural, and Utility Relocation	4	43 months	$ 325 million	11/5/2013	53 months	$ 372 million	23%	15%
96th STREET STATION	6/22/2012	E.E. Cruz/Tully Construction	Station Finishes, MEP Systems, Ancillary Buildings, and Entrances	7	42 months	$ 324 million	8/7/2017	61.5 months	$ 411 million	46%	27%
86th STREET STATION	7/8/2009	J.D'Annunzio & Sons, Inc.	Excavation, Utility Relocation, and Road Decking	5	19 months	$ 34 million	11/16/2011	28 months	$ 41 million	47%	19%
86th STREET STATION	8/4/2011	Skanska/Traylor JV	Heavy Civil/Structural	5	37 months	$ 302 million	12/16/2014	52 months	$ 326 million	41%	8%
86th STREET STATION	6/12/2013	86th Street Constructors	Station Finishes, MEP Systems, Ancillary Buildings, and Entrances	5	35.5 months	$ 208 million	9/29/2017	51.5 months	$ 266 million	45%	27%
72nd STREET STATION	10/1/2010	Schiavone/Shea/Kiewit	Cavern Mining, G3/G4 Tunnels, and Heavy Civil/Structural	3	39 months	$ 447 million	1/14/2014	39.5 months	$ 448 million	1%	0%
72nd STREET STATION	2/14/2013	Judlau Contracting	Station Finishes, MEP Systems, Ancillary Buildings, and Entrances	5	33 months	$ 258 million	8/3/2017	56.5 months	$ 347 million	71%	34%
63rd St. Stn.	1/13/2011	Judlau Contracting	Reconstruction	6	40 months	$ 176 million	12/29/2017	83 months	$ 229 million	108%	30%
SYSTEMS	1/18/2012	Comstock Skanska JV	Track, Power, Signals, and Communications	4	55 months	$ 262 million	7/12/2018	78 months	$ 336 million	42%	28%
DESIGN & CM	5/31/2007	PB Americas	Consultant Construction Management		91 months	$ 81 million	8/31/2021	173.5 months	$ 204 million	91%	152%
DESIGN & CM	12/20/2001	Aecom-Arup JV	Design and Engineering Services		183 months	$ 187 million	3/31/2021	210 months	$ 451 million	15%	142%

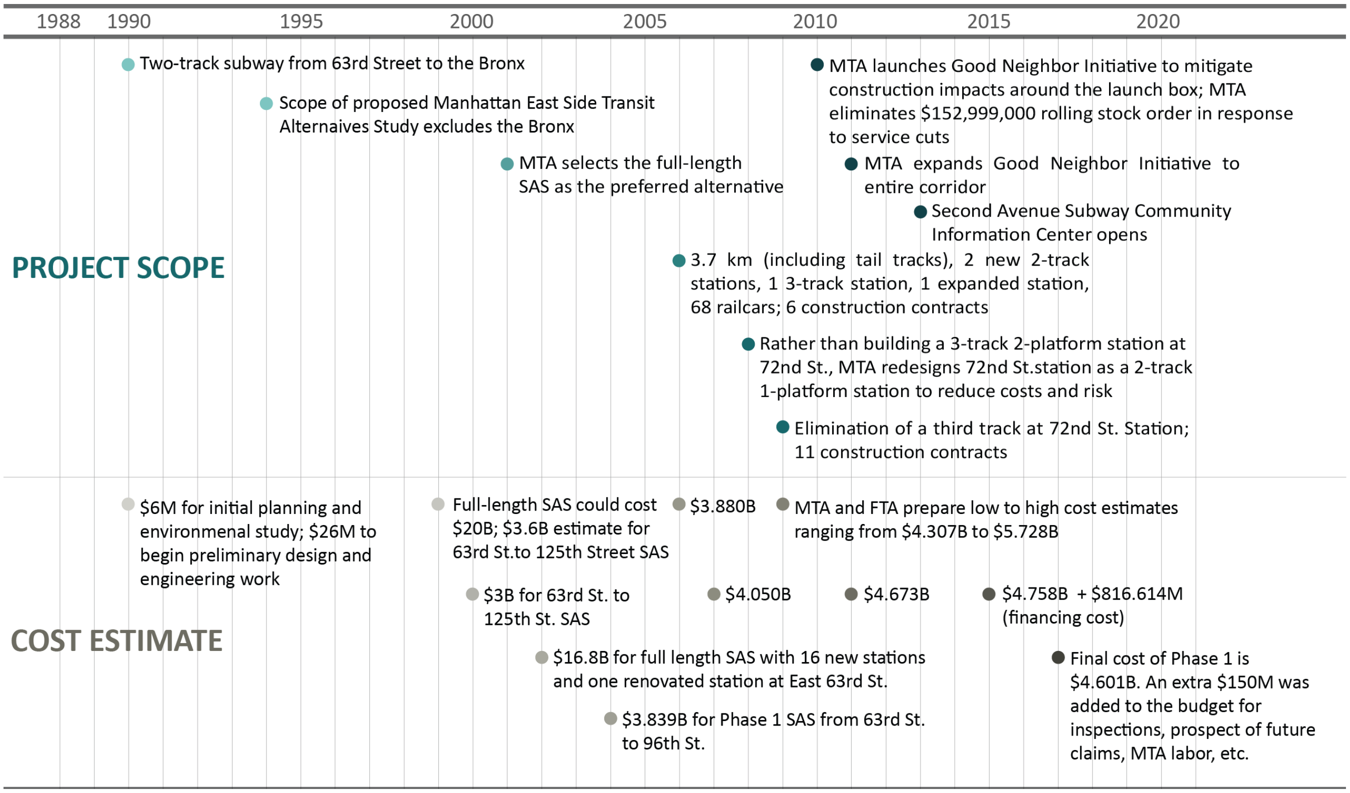

Figure 4. Phase 1 of the Second Avenue Subway Timeline: Scope and cost estimate

As soon as the project began things changed. While change is common on large-scale, multi-year projects, especially ones that rely on notoriously inaccurate as-built drawings for underground utilities, these changes invariably add costs and delay. At this early date in the project, the changes were largely programmatic, though the tunneling contract was delayed by the discovery of an unanticipated subsurface wall and utilities while relocating utilities to dig the launch box. Over the course of 2008, the anticipated revenue service date slipped from June 2014 to June 2015 to March 2016 because of contract repackaging and tunneling delays (Urban Engineers 2007c; Urban Engineers 2008a; Urban Engineers 2008b).[18]

[18] In reading through the Project Management Oversight reports, it's clear that from month to month the outlook on the start of revenue service changes. So even though a 2008 report claimed March 2016 as the opening date, there are later reports that point to June 2015. Since we already know the project didn't open for revenue service until January 1, 2017, we think it's reasonable to chronicle this uncertainty. Additionally, even though the Oversight reports state one thing, the agency and the media have different understandings of the project timeline.

First, the MTA broke the three station contracts into smaller packages to reduce the value of each contract to ensure bidders could secure payment and performance bonds and bid on the packages.[19] The MTA initially proposed going from six to nine contract packages before determining the ideal number of construction contracts was 12. This was later revised to 11, before settling on 10 construction contracts in 2010. The basic contract framework was: TBM tunneling and access shafts at 69th and 72nd Street, 63rd Street Station rehabilitation, systems, and then, finally, instead of one contract per station, as was initially planned, each of the three new-build stations would have three contracts each (Urban Engineers 2008b).[20] Second, in going from six construction contracts to 12, the CCM and the Design contracts had to be adjusted to account for the expanded coordination responsibilities, the redistribution of components and tasks from six to 12 contracts, and rephasing the bidding and construction sequence of each contract (Urban Engineers 2008b). In the case of the CCM contract, it had to be modified to account for the greater coordination responsibilities across 12 contracts. By December 2008, the value of the contract had increased from $80.9 million to $91 million.[21] Third, in 2008, the MTA redesigned the 72nd Street Station. The new design reduced the number of tracks from three to two and platforms from two to one. This change limited construction risk by reducing the overall station-cavern's width from 30 meters to 21 meters and cut costs by an estimated $90 million, though the redesign work triggered a $26.5 million change order (Urban Engineers 2009a; Urban Engineers 2009b; MTA Capital Construction 2008).

2.3 The stress of construction

Decades-long capital projects invariably have the bad luck of overlapping with natural disasters, broader economic downturns, pandemics, and other unforeseen events. Phase 1 of the Second Avenue Subway construction started just as the price of commodities rose in 2008. In adjusting to the economic downturn, the MTA estimated that the

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[19] A payment bond guarantees that contractors can pay their subcontractors, laborers, and cover any other costs they may incur. A performance bond, similarly, guarantees that the contractor will complete the work. If the contractor is unable to complete these tasks, the bond allows the MTA to recoup the cost of the contract.

[20] Based on interviews and document review, it is clear that the MTA studied and considered a range of contract packages before settling on the 10 primary construction contracts.

[21] Again, change is extremely common for transit projects. Just as we see in Turkey, Boston, and Italy, things change once construction starts. Thus, it's normal for the construction management functions to expand and be pressed into overtime to account for these changes. On the one hand, this is a good reason to have the right mix of internal experts at the agency, a la Metropolitana Milanese in our Italian case, to navigate this challenging process rather than relying on a mix of expensive consultants who require new scopes of work, change orders, and an additional layer of coordination to mobilize. On the other hand, Mysore Nagaraja, the former head of capital construction at the MTA, has stated that relying on consultants allowed him to hire specialized experts quickly and avoid bureaucratic red tape (Plotch 2021, pp.195-196).

costs of its megaprojects, including Second Avenue, East Side Access, and the Fulton Street Center, had increased by $1 billion dollars, from $15 billion to $16 billion. MTA Board Chair Dale Hemmerdinger tried to explain the additional costs, in part, by pointing out that "[t]he prices of steel and concrete, materials the MTA needs in bulk, have jumped 91% and 25% respectively" (Donohue 2008).[22] Thus, in 2008, as the State was finalizing the state budget and the MTA capital program, the MTA reviewed its projects and announced that the new cost estimate for Phase 1 of the Second Avenue Subway had increased to $4.347 billion (MTA Capital Construction 2009).

After receiving an FFGA in 2007, construction of Phase 1 began in earnest; however, early on, construction mostly meant relocating utilities and preparing to dig the launch box between just south of 95th Street to just south of 92nd Street. Programmatic delays hampered the start of the construction phase, but once construction began and more contracts were tendered, the project encountered additional kinds of delays and cost drivers: namely interruptions to construction because of fragile buildings that needed repairs, support, and structural strengthening; unexpected ground conditions that required ground freezing to allow the TBM to drill safely; complaints about noise and air quality from blasting station caverns; and ongoing design changes such as the entrances of stations, ancillary facilities, and the overhaul of the 72nd Street Station design. Navigating these challenges would have been difficult regardless, but the lack of comparable subway-building experience in New York did not help things along, even with a growing team of consultants who took on final design, construction support, constructability reviews, construction management, and coordination responsibilities.

The MTA did have people working on Phase 1 who had worked on the 63rd Street immersed-tunnel project crossing the East River that opened in 1989 and new station projects. Additionally, some of the contractors had worked on projects in D.C. and Boston, but no one had immediate experience managing a project like Second Avenue. Furthermore, several people told us that the pre-construction work suffered from minimal engagement with property owners and relied on others to resolve challenges, like having the New York City Department of Buildings (NYC DOB) enforce code violations and contractors to implement construction methods that could achieve adequate excavation rates without disturbing fragile building foundations in the construction zone all delayed construction at the most inopportune time: once contracts had already been signed and construction was underway (Personal Interview A 2021; Personal Interview C 2022; Personal Interview D 2022; Personal Interview E 2022).

[22] While this explanation is intuitive, Phase 1's post-2008 contracts came in below cost estimates as more bidders competed for MTA work.

While New York is not as old a city as Rome, Istanbul, or Athens, it does have buildings in need of repair. During construction of the TBM launch box in 2009, S3 Tunnel Constructors was prepared to begin using drill and blast techniques to excavate the launch box, when NYC DOB issued emergency vacate orders and required building owners to stabilize their buildings before allowing anyone to return to the buildings or for blasting to proceed (Horodniceanu 2009; NYC Department of Buildings 2009).

Even though blasting had been prohibited, work moved forward. S3 reverted to slower mechanical methods of excavation, such as hoe ramming and rock drilling. Whether or not construction of the launch box caused damage to the buildings, there were building violations predating the start of construction, the tunneling contract was now six-and-a-half months behind schedule and each day of delay exposed the MTA to $30,000 to $60,000 in claims from the contractor. The MTA agreed to pay $785,000 to shore up the buildings and avoid additional delays and $1,200,000 to continue excavation using slower methods (Metropolitan Transportation Authority 2010; Metropolitan Transportation Authority 2011a).

Even as the pace of the launch box construction slowed, the MTA pressed ahead with two more contracts in 2009. First, in May 2009, an E.E. Cruz and Tully Construction joint venture was awarded a 43-month $325-million contract to build the 96th Street Station box, relocate utilities, and ancillary facilities, and rehabilitate and retrofit the existing tunnels running from 99th to 105th Street (Urban Engineers 2009c). Even though only two bidders submitted proposals for the first contract, this contract received four submissions. Initially, Perini/Tutor Saliba had been selected, and it was anticipated that the contract would be awarded in January 2009, but concerns about the group's performance on other projects disqualified them and delayed the award (Urban Engineers 2009b). In July, J.D. Annunzio & Sons was awarded a 19-month $34-million contract to provide utility relocation, road decking, and vertical starter shafts for construction of the 86th Street Station (Urban Engineers 2009d). The MTA received five bids for this contract, and three of them came in under the revised $41 million estimate (Urban Engineers 2009e).

After three years of relocating utilities, fixing and stabilizing buildings, and, finally, digging the capacious 244-meter-long by 18.9-meter-wide by 19.8-meter-deep launch box, in May 2010, the first TBM drive began (Urban Engineers 2010a; Tirolo Jr. et al. 2013).[23] S3 Tunnel Constructors used a $25 million reconditioned 485-ton Robbins Main Beam 6.7-meter diameter TBM christened Adi. Over the course of 16 months and an average advance rate of 15 meters per day, S3 dug the northbound and southbound tunnels, a combined 4,600 meters (Urban Engineers

[23] As a point of contrast, in our Istanbul and Italian cases, we learned that launch boxes can be dug in one year or less.

2011a; Urban Engineers 2011b). As with every other aspect of this project, uncertainty and change loomed large at the outset of the TBM drive.

While digging the starter tunnels for the TBM, S3 determined that the ground conditions on the east side of Second Avenue differed from the hard-rock conditions described in the geotechnical baseline report and were unsuited to its hard-rock TBM. Rather than getting a new machine designed to bore through softer ground, S3 initiated a ground-freezing program to make the ground conditions between 90th and 91st Streets more conducive to using a hard-rock TBM (Urban Engineers 2010b; Robinson 2011; Tingley 2012).[24] Since the tunneling contract was behind schedule and ground freezing would take three months to complete, S3 ended up tunneling the west tunnel first and extending the TBM drive 675 meters to 65th Street.[25] In addition to triggering design changes, re-sequencing tunneling operations, and modifying contract packaging, S3 received $18.7 million in Additional Work Orders (AWOs) for tunneling work; $6.6 million for ground freezing above the east tunnel, and $2.6 million for drilling through the freeze zone and construction of a concrete inner liner (Metropolitan Transportation Authority 2011b MAY; MTA Capital Construction 2011; Urban Engineers 2011c).

As ground freezing plans were being drawn up, the MTA received three bids for the 72nd Street Station Cavern contract. Two of the three bids came in under the MTA's $448 million estimate; however, one bidder informed the MTA that it had made a computational error, which led to its bid being 29% less than the estimate. This contract, in particular, had its scope reduced by about $150 million over the course of repackaging and reallocating scope because of the decision to eliminate the third track at 72nd Street and by adding the 675 meters of tunneling to S3's contract (Urban Engineers 2010c). The MTA selected Schiavone, J.F. Shea, and Kiewit's (SSK) 39-month, $447,180,260 bid (Urban Engineers 2010d).

2011 was a busy year for Phase 1 of the Second Avenue Subway. S3 completed tunneling both the northbound and southbound tunnels, the MTA awarded two more station-construction contracts, and J.D. Annunzio & Sons completed its utility relocation and starter shaft work for the 86th Street Station. In January, the MTA awarded a 40-month, $176 million 63rd Street Station retrofit contract to Judlau (MTA Capital Construction 2011a). In August, Skanska/Traylor JV beat out four other bids and was awarded the 37-month, 86th Street Station cavern and heavy civil contract for $302 million. The Skanska/Traylor bid came in at nearly $100 million under the construction cost

[24] Ground freezing was also used for the 7 Line Extension to Hudson Yards.

[25] The initial plan was to stop the west bore at the northern crossover, literally where tracks cross over, by the 72nd Street Station. One of the 72nd Street Station contracts would include tunneling the remaining 675 meters.

estimate and $33 million less than the next lowest bid. Even though the MTA received these bids in February, the Skanska/Traylor submission needed additional clarification to ensure it complied with Buy America, which delayed approval until August (Urban Engineers 2011a).

2.4 Localized impacts

In addition to reaching meaningful project milestones in 2011, there was increased public pushback as construction impacts became unavoidable. General complaints about garbage, noise, and disruptions were amplified by more specific complaints about drilling and blasting the 72nd Street Station's cavern. The MTA instituted three broad changes in response to greater scrutiny. First, the MTA extended its Good Neighbor Initiative to the entire construction zone. The Good Neighbor Initiative began as an effort to make the launch-box area tidier by increasing garbage collection, installing additional wayfinding signage, wrapping the construction-zone fencing, and tending to local businesses' concerns. Second, the MTA launched a community outreach effort to address the concerns of those living within the construction zone. This effort included opening a community outreach center on second avenue and holding quarterly public meetings to solicit feedback about how it could better mitigate construction impacts (Heckscher 2011; Metropolitan Transportation Authority 2012a). Third, the MTA decided to reduce the blast window for heavy construction from 18 hours to 12 hours (MTA Capital Construction 2011b). In addition to limiting the blasting schedule, SSK, the joint venture building the 72nd Street Station, was tasked with improving efforts to contain the dirt and dust impacts from blasting, which, inadvertently, got worse as the blasting schedule became shorter and reduced the gap between blasts (Sharp and Zimmer 2011).

Responding to neighborhood concerns is critical to managing a project like Phase 1. Addressing these concerns, however, comes at a cost. In late November, the MTA halted blasting at the 72nd Street Station construction site for two weeks while the contractor figured out how to address these concerns. This was in addition to restricting the blast schedule, which meant change orders: SSK received $2,175,000 for rescheduling construction 72nd Street Station, and Skanska/Traylor agreed to a $5,200,000 change order for the 86th Street Station work (Metropolitan Transportation Authority 2011b; MTA Capital Construction 2013 Q1).[26] In addition to these efforts around blasting, the MTA paid the CCM $1,117,100 to conduct air quality studies at the 72nd Street and 86th Street Station sites and

[26] At the 86th Street Station site, blasting was allowed until 8:00 PM rather than 7:00 PM.

develop a mitigation strategy (Metropolitan Transportation Authority 2012b). Expanding the Good Neighbor Initiative to the entire work zone cost an additional $3,716,340 (Metropolitan Transportation Authority 2012a).

While 2012 and 2013 saw the MTA finalize the four remaining Phase 1 construction contracts, in 2012, New York State committed to funding, or, more accurately, allowing the MTA to take on more debt to fund the missing $13 billion from its capital plan. Funding for Phase 1 stretches across multiple capital plans, but the 2010-2014 plan accounted for about $1.5 billion of the project's local match, which by 2012 was projected to be around $3 billion (Haughney 2012; Urban Engineers 2015a). By securing these funds, uncertainty about how to pay for the four remaining contracts, mainly station finishes contracts, was put to rest. Since large capital construction projects like Phase 1 are carried out in stages, it is not critical to bid out every contract at the same time; however, uncertainty over funding can lead to tendering delays, which inevitably, at its most benign, lead to inflation-driven cost escalation and schedule delay, which was a frequent concern of the Project Management Oversight Consultant (PMOC) retained by the FTA to monitor the project (Urban Engineers 2012a, p.4).

Even after securing the funding to pay for Phase 1 construction, the MTA still needed to manage construction mishaps, community objections to specific station locations, and Superstorm Sandy, which wrought more than $5 billion in damage to the existing subway system (Metropolitan Transportation Authority 2013a). While the MTA had taken precautions to minimize the impacts of mining station caverns and shafts—restricting the blast schedule, studying the air quality along the corridor, and improving muckhouse facilities and dust collection—in August 2012, while excavating a 22.5 meter by 22.5 meter shaft for the 72nd Street Station, an errant blast sent a steel deck plate used to secure the site rocketing into the air. Fortunately, no one was injured, though there was some property damage. The MTA immediately suspended all work at the site while it investigated the incident and addressed shortcomings in its blast monitoring (MTA Capital Construction n.d.).

Blasting challenges aside, the MTA faced fierce pushback from building owners when it came to siting entrances for the 72nd Street and 86th Street stations. Three years after finalizing Phase 1 designs and awarding the 72nd Street Station construction contract, the MTA moved the 72nd Street Station entrance planned for 301 East 69th Street to the sidewalk. Rather than wrestling with unwieldy utilities and a disgruntled co-op board, the MTA took advantage of a new bicycle lane along Second Avenue to gain approval from the New York City Department of Transportation (NYC DOT) to use the sidewalk for two entrance canopies (Chung 2004; Federal Transit Administration 2013). As with all midstream changes, this change cost money: the MTA approved a contract modification for $9,470,000 in 2019 including compensable delays from this redesign (Metropolitan Transportation Authority 2018).

At 86th Street, Yorkshire Towers filed a second lawsuit challenging the location of two sidewalk entrances sited on either end of the building's horseshoe-shaped driveway. While this lawsuit was dismissed, again, the localized impact and reception of Phase 1 was not uniform in New York and along the corridor. Joseph Ceccarelli, one of the lawyers representing Yorkshire Towers, captured the mixed reception of the project when he told DNAinfo (Zimmer 2011) during the initial lawsuit that "'We're not against the Second Avenue subway. We're New Yorkers. We need it,' Ceccarelli said. 'We're just against the siting of the entrance.'"

Superstorm Sandy wreaked havoc on the existing subway system causing billions in damages. Its immediate effect on the Second Avenue Subway was less catastrophic. Following the damage done to the recently opened $530-million-dollar South Ferry Station, which required another $340 million in repairs, Sandy prompted design changes meant to protect against similar storms (Rivoli 2017). This meant redesigning elements vulnerable to flooding, such as station entrances, manhole covers, sidewalk ventilation grates, and entrances to ancillary buildings rather than rebuilding tunnels and stations (Taylor et al. 2019).

2.5 Managing contract interface challenges

In 2014, seven years after construction started, more than 50% of the project had been completed. The MTA's focus shifted from tendering contracts to closing them out, transitioning from initial contract construction milestones to access dates for the later contracts, coordinating interfaces, and figuring out how to meet the target revenue service date of December 30, 2016. The 86th Street utility relocation contract and the tunneling contract wrapped up in 2011 and 2012. At the end of 2013, the 96th Street heavy civil structural contract achieved substantial completion (Urban Engineers 2013). Similarly, 2014 was bookended by the completion of the 72nd Street Station heavy civil structural contract in January and the 86th Street heavy civil structural contract in December (Urban Engineers 2014a; Urban Engineers 2014b).

Since Phase 1 had 10 construction packages, and basically followed a structure of one contract to build the station box and another for finishes, the integration of these workflows determined the schedule. Slippage in the station-construction contracts, meant slippage in the finishes contracts, and slippage in the systems contract, all of which threatened the December 30, 2016 revenue service date target. Plotch (2020, pp.233-234) details these contract interface challenges when he describes the difficulties encountered by systems contractor Salvatore DeMatteo:

> DeMatteo began installation where he could, but he had to wait until many other contractors completed their assignments. His workers needed to connect equipment to permanent power supplies that were not yet available, and to install cables through conduits that had yet to be put in place. His team could

not hang antennas until ceiling panels were installed or connected heat detectors to elevators that had not been lowered into stations.

Even though there had been delays since 2007 and half of the construction contracts had achieved substantial completion, now that 2016 was only a year or two away, it was hard to picture a scenario where everything was delivered on time. In September 2015, the PMOC (Urban Engineers 2015b SEPTEMBER) warned that "[e]ach of the five remaining construction contracts has experienced significant delays," and "there is diminishing evidence to support [MTA Capital Construction's] position that it can achieve the [revenue service date] by December 30, 2016."

2.6 December 31, 2016 or else

At the start of 2016, the MTA implemented a $66 million acceleration program to ramp up construction, testing, and management efforts to open Phase 1 of the Second Avenue Subway on time. The MTA agreed to pay an additional $17.5 million to extend shifts, work weekends, add laborers, and establish specific contract milestones to complete the 72nd Street Station so that testing and training could begin on September 1, 2016. The MTA repeated this process by paying an additional $18.5 million to finish the 86th Street Station, $14 million to close out the 96th Street Station, and $16 million to ensure the systems contractor installed all 22,000 linear feet of track, communications systems, and traction power (Metropolitan Transportation Authority 2016a; Personal Interview F 2022).

While more money meant more laborers, greater productivity per day, and more support for construction, the other catalyst for completing the project on time was Governor Andrew Cuomo. Even though Governor Cuomo was first elected governor in 2010, he became interested in the project in late 2015. In our interviews, a number of people told us that the governor pushed every button and pulled every lever to get the project done before the close of 2016 (Personal Interview B 2021; Personal Interview C 2021; Personal Interview D 2021; Personal Interview F 2022; Personal Interview G 2022). One senior consultant who had been hired in 2015 to help complete the project on time told us that transit projects move slowly because coordinating across a handful of general contractors and dozens of subcontractors and vendors requires waiting. During Phase 1's acceleration period, however, there was a palpable urgency to get things done; thus, instead of taking weeks and months to make a decision about who would move a conduit or pour concrete or fix a problem with the escalators and elevators, "people were jumping on planes [from across the country and globe] to get the job done the next day" (Personal Interview F 2022). Without the governor's direct involvement, Phase 1 would not have opened on time, but, as

Plotch (2022, pp.234-235) explains, getting things done on time came at an enormous cost to the MTA's other priorities:

> When making decisions about the Second Avenue subway, MTA officials always had to balance various factors, including budget, schedule, and quality. Cuomo changed the MTA's priorities to emphasize speed. As a result, some factors were deemphasized, such as NYC Transit's concerns about maintainability, budget officials' worries about cost overruns, and engineers' expectations that they would thoroughly test every single component. The governor's insistence on meeting the New Year's deadline would consume the MTA as it turned its attention from other projects, other escalators, and other signal systems.

Once the governor decided that the project had to open by the end of 2016, he elevated the project schedule above everything else.

Even though the Second Avenue Subway's alignment is entirely underground, Second Avenue itself was ripped up to relocate utilities, dig access shafts, and station entrances. Working with the NYC DOT and New York City Parks Department (NYC Parks), the MTA paid to replace street trees, paint newly adopted bus and bicycle lanes, and rebuild streets and sidewalks to a higher standard along Second Avenue and many of the intersecting side streets. In March the MTA granted E.E. Cruz/Tully Construction an additional $4 million, plus an earlier infusion of $3.75 million, to attend to these street-level issues (Metropolitan Transportation Authority 2016b). It's worth noting that the MTA agreed to surface restoration improvements from 88th Street to just north of 105th Street in order to create a consistent streetscape along Second Avenue, even though the southernmost portion of the 96th Street Station is just south of 92nd Street.

On December 31, 2016, Governor Cuomo hosted a 500-person New Year's Eve party at the 72nd Street Station. While party goers started at 72nd Street, they eventually boarded a 96th-Street-bound Q train and visited all three newly built stations (Barone 2017). The next day, January 1, 2017, Phase 1 of the Second Avenue Subway opened for revenue service. Despite achieving this milestone, the project was incomplete. In order to host the party and get Phase 1 ready for revenue service, New York City Transit issued Temporary Code Compliance Certificates, but according to the PMOC there were still 17,260 discrepancies on the "Observations List," which was a product of accelerating construction and eschewing regular procedures (Urban Engineers 2017a).[27] By trading speed for normal procedures, the PMOC worried that construction quality was compromised.

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[27] The Temporary Code Compliance Certificates required that all work be completed by March 1, 2017, 60 days after the certificates were issued. This deadline was not met (Urban Engineers 2017b). Discrepancies are any deviations from the designs. This could be as benign as an outlet plate missing.

As soon as Phase 1 opened, cracks began to emerge. On January 1, there were already reports of out-of-service elevators, leaks in stations, and repairs to structural elements (Urban Engineers 2016; Fitzsimmons et al. 2017). In May, an entrance at the 86th Street Station had to be closed because three escalators were out of service after faulty sensors set off station sprinklers (Weaver 2017). A 2019 MTA Inspector General report found that after 15-months of observation only three of 32 escalators in the newly built stations met NYCT's escalator performance goals (Pokorny 2019). To add insult to injury, all of this happened after the MTA approved an additional $5 million for enhanced maintenance and repair services for escalators and elevators at the 72nd Street, 86th Street, and 96th Street Stations from December 31, 2016 to June 30, 2017 (Metropolitan Transportation Authority 2017a).

While these breakdowns were obvious to riders, there were also less visible system integration and safety testing delays that were still being addressed after January 1, 2017. Problems with the fire safety system were so dire that the MTA spent $6.5 million to hire human fire watchers at each station while the system was reprogrammed (Rubenstein 2017).[28]

In addition to these challenges, now that the system was operating 24 hours a day, finding time to address outstanding items, namely compliance issues rather than significant operational concerns, became more difficult because trains were in service, passengers were in the stations, and consultants were transitioning to other projects. Even though revenue service began on January 1, 2017, the consultant construction management contract didn't achieve substantial completion until August 31, 2021.

[28] During this period in the MTA's history there were approximately 1,000 fires per year (Metropolitan Transportation Authority 2017b).

3 Analysis

In this section we shift from the narrative timeline presented in Section 2 to a deeper investigation of project specific elements that drove costs. Specifically, we show how intergovernmental coordination and utilities, labor wages and staffing, procurement and risk, and station design impacted costs throughout the course of Phase 1. Furthermore, by focusing on these factors, more general themes related to a lack of leadership, strict adherence to existing protocols and regulations, tensions between capital and operations funding, power asymmetries all contribute to schedule delay, over design, and greater costs. There is no single solution that will immediately cut budgets by 50%. We believe, however, that highlighting these issues and showing how they drive costs, slow construction, and increase payouts, especially in contrast to some of our other cases, should begin a conversation about why we insist on doing things the way we do them. Leadership, especially from the governor and mayor, needs to empower the MTA to use the same creative problem solving it deployed to secure a $1.35 billion FFGA to reduce costs and speed up construction.

We assembled data for this section from typical sources, such as newspaper articles, books, project documents, reports, articles, and presentation materials prepared by the MTA, FTA, and people who worked directly on the project. We also conducted more than 80 one-on-one and group interviews with contractors, suppliers, manufacturers, risk assessors, lawyers, cost estimators, sub-contractors, designers, engineers, laborers, current and former MTA executives and staff members, current and former transit agency executives and staff members outside of New York, local officials who interacted directly with the project, and advocates to better understand specific moments and cost drivers in the project's development.[29]

[29] Many of these interviews also included extensive follow up, such as clarifying emails, drawings, charts, documents, and follow up interviews.

3.1 Intergovernmental and utility extraction

Staging construction

Before Phase 1 construction began, the MTA had to figure out how to build underneath Second Avenue's maze of legacy and more recent urban infrastructure. This meant securing agreements from the New York City Department of Transportation (NYC DOT), New York City Department of Environmental Protection (NYC DEP), New York City Parks Department (NYC Parks), New York City Department of Buildings (NYC DOB), Fire Department of the City of New York (FDNY), Consolidated Edison (Con Ed), Verizon, Empire City Subway (ECS), and others to close lanes of traffic, cut open streets for starter shafts and the TBM launch box, move pipes and utilities, get permits to use explosives, and stage construction. In Istanbul or Milan, those local governments contributed land to the project to build station entrances or shut down traffic on key streets to ease conflicts and keep the project moving. For Phase 1 of the Second Avenue Subway, the MTA had to negotiate separate agreements with city agencies and utility companies and agree to improvements, be it replacing old pipes with newer, larger ones made of more expensive materials, and usage payments to stage construction in an NYC Parks playground on Second Avenue. Overcoming these barriers was key to getting the $4.601 billion project built, but satisfying every third party who has the ability to withhold a permit or slow down construction came at a cost. A review of project documents suggests $250-300 million was spent on these kinds of arrangements, but this doesn't include the delays incurred by contractors, which add costs in additional claims (Torres-Springer 2022).[30]

Early on in our interviews, we spoke with contractors, consultants, and former MTA staff members who were named in media reports and project documents. When we interviewed these experts, we often began by asking an open-ended question, "So why did Phase 1 cost $4.6 billion?" Invariably, respondents would rattle off a litany of plausible reasons. What helped focus our inquiry, however, was when these experts offered concrete examples. The first interesting lead we received that had not been mentioned explicitly in our document review was a $15 million deal the MTA made with NYC Parks in 2004 to temporarily stage construction at the Marx Brothers Playground on Second Avenue between 96th and 97th Streets (Figure 6)(Personal Interview E 2021).

[30] These kinds of arrangements aren't unique to New York. In addition to examples we documented in our Green Line Extension case study, transit leaders in other American cities have told us about buying fire trucks for municipalities that complain that they don't have the resources to fight fires at newly built rail stations or along a stretch of guideway or funding construction on university campuses (Personal Interview H 2022).

MTA leaders like Joe Lhota, the former MTA Chair, and Dr. Michael Horodniceanu, the former head of MTA Capital Construction (MTA CC), often mentioned the sheer population density along Second Avenue on the Upper East Side as a significant driver of costs (Rosenthal 2017). While population density does drive costs, the more relevant driver in this instance was land saturation. The roughly $15 million deal the MTA struck with NYC Parks to use the westernmost section of the Marx Brothers Playground illustrates how challenging it is to find enough space in a crowded urban environment where buildings occupy most lots and traffic and parked cars blanket the roadways. Under these conditions, where was the MTA to find enough space to store construction materials, provide locker rooms for laborers, or office space for field engineers and supervisors who need to manage and dig the 244-meter-long by 18.9-meter-wide by 19.8-meter-deep TBM launch box and the 490-meter long 96th Street Station? In the Final EIS (2004, 3-24), the dimensions of these sites are described precisely:

> In addition [to the launch box], equipment storage and construction activities at each shaft site would require that a staging area with a minimum of 40,000 square feet surface area (and a preferred 50,000 to 80,000 square feet [4,645 meters to 7,432 square meters]) abut each shaft site. The minimum of 40,000 square feet [3,716 square meters] is the equivalent of approximately half the width of Second Avenue for approximately four blocks. Ideally, each staging site would measure about 200 feet [61 meters] by 200 feet [61 meters]; however, given the approximate 100-foot [30 meters] width of Second Avenue from building line to building line and the density of development along the avenue, sites with those dimensions would be difficult to find, even if adjacent off-street properties are identified for use in combination with portions of the street right-of-way.

Paying $15 million to use Marx Brothers Playground allowed the MTA to secure a convenient site to get underground without going through a contentious and potentially more costly and uncertain eminent domain process. A former NYC Parks official who participated in the negotiations told us that there was no standard process for this type of deal; thus, officials at NYC Parks asked themselves, "If [the MTA] has to buy this land what would it cost? What is the most money [NYC Parks] could get" (Personal Interview I 2022)? This official acknowledged that the MTA negotiated in good faith and was "very honorable," and that NYC Parks did not want to obstruct Phase 1, especially since Marx Brothers Playground was "lightly used." Despite embracing this spirit of cooperation, NYC Parks officials understood that they were in a position to extract some of the project's $4-$5 billion budget for themselves and that "a smart [agency] is going to ask for as much as they can" (Ibid.). Ultimately, NYC Parks received $11 million in 2004 ($15 million in 2020 dollars) to stage construction at Marx Brothers Playground, $1,925,000-$2,500,000 to restore the playground once construction was completed, $1,322,000 to plant 444 new trees, and more than $600,000 to hire five park employees to work in nearby playgrounds (Lapp 2004; New York City Parks Department n.d.).

Figure 5. Marx Brothers playground, before (10/06), during (08/12), after (05/18) construction and in 2022

When we described this scenario to our contacts in Italy and Istanbul, they seemed confused as to why the MTA would have to pay to use public land. In fact, the city did contribute land to the MTA for the construction of the 7 Train extension to Hudson Yards. The MTA had to pay for this land because neither the governor nor mayor intervened to help move the project along. Without champions with the power to bring agency heads to the table and work things out to benefit taxpayers, each agency holds out for its payout to help renovate facilities or hire additional staff. Compounding this issue is the federal government's largesse. With money coming in from Washington D.C., the MTA had additional resources to take on the extra costs to get things done.

Getting to yes

When looking at the proposed plans for Phase 2 of the Second Avenue Subway, one thing that stands out is that project delivery will follow a different format than Phase 1. Rather than procuring a final design before tendering contracts to build Phase 2, a traditional Design-Bid-Build procurement, the extension from 96th Street to 125th Street and Lexington Avenue will be delivered via a Design-Build procurement with four contract packages. The first contract will be an advanced utility relocation contract (MTA Construction & Development 2021). For our immediate purposes, we highlight this because the former head of MTA CC, Dr. Michael Horodniceanu, explained at a New York Law School lecture that one of the main lessons learned from Phase 1 was the need to better locate utilities and move them prior to the start of construction (Horodniceanu 2017). In our interviews with planners, designers, contractors, and engineers, we were told that in the design for Phase 1, the decision to build deep mined stations and deploy a TBM, was made, in part, to avoid the conflicts that arise during utility relocations (Personal Interview F 2021; Personal Interview G 2021; Personal Interview C 2021; Personal Interview G 2021).

Similar to the challenge of finding a suitable location to stage construction in a city where buildings and active roadways dominate the landscape, New York has power, water, electrical, gas, steam, communications, and sewerage infrastructure running beneath its streets. When building a subway, it is inevitable that conflicts will emerge as access shafts and launch boxes are excavated from the surface. As an additional challenge, the exact location of all of these utilities is not well known. One expert described digging up New York's streets as, "performing surgery without knowing where anything is" (Personal Interview K 2022). Finally, the MTA was required to coordinate and obtain approvals from utility companies and city agencies, namely Con Ed and NYC DEP, to ensure these conflicts were managed satisfactorily.

During Phase 1 construction, the MTA did issue one advanced utility contract. Rather than target the whole corridor, this contract focused on the 86th Street Station area.[31] Even though this $40.5 million contract is a tiny fraction of the overall construction costs, our interviews and review of project documents demonstrate that utilities drive costs, design decisions, and schedule delay in New York and across North America.[32] One Canadian transit agency manager went so far as to say that "transit projects are just very large utility projects with a bit of rail added on. The lion's share of my work is moving pipes and ducts out of the way for a very quick and easy installation of some concrete and rail" (Personal Correspondence A 2022). As glib as this quote is, it does capture the magnitude of utility-related challenges faced by agencies and contractors when planning, designing, and constructing projects.

The 86th Street Station advanced utility contract called for excavating two starter shafts to provide access to carve out the 86th Street Station box, including the ancillary caverns. The contractor replaced, supported, and relocated all of the utilities in the vicinity of 82nd and 84th Streets and 86th and 87th Streets and installed a road decking system to maintain the flow of traffic along Second Avenue while digging those shafts.

[31] Utility relocation was bundled into the other station contracts.

[32] The initial contract had an award value of $34 million. Over the course of the 28-month contract there were an additional $6.5 million in contract modifications.

Even though the contract began in July of 2009, NYC DEP failed to approve the MTA's utility replacement plans until February of 2010 (Urban Engineers 2010e).[33] Part of the delay stemmed from NYC DEP's desire to have the MTA replace the existing 48-inch diameter cast-iron pipes in the northern and southern construction zones with 60-inch diameter steel pipes (Urban Engineers 2010 March; Personal Interview K 2022). While the MTA and NYC DEP renegotiated terms, the contractor was unable to move, support, or replace any of NYC DEP's water mains, which delayed construction and impacted future 86th Street Station contracts. This delay also entitled the contractor to a $2,240,000 lump sum impact cost settlement, going beyond just the DEP-driven delays (Metropolitan Transportation Authority 2013b). The MTA balked at this request, exposing itself to $15,000 a day impact costs, because swapping out a 48-inch diameter cast-iron pipe for a 60-inch diameter steel pipe is not as simple as a one-for-one substitution.[34]

First, installing a 60-inch diameter pipe of any material calls for a tapered design to transition from the new 60-inch diameter pipe to the existing 48-inch diameter pipes on either side of it. Thus, the contractor needs to buy and replace more lengths of pipe and carry out additional excavation, removal, support, and backfill rather than a more straightforward one for one swap. Second, connecting steel and cast iron requires customized flanges and in-field welding, all of which add costs, delay, and risk. Third, utilities are laid side by side and stacked above and underneath one another underground, expanding the footprint of one pipe impacts the layout of other utilities. Thus, installing a 60-inch diameter pipe would also mean moving and reorganizing the adjacent water and gas mains and telephone ducts, an additional cost and risk, in order to accommodate the larger pipe. Fourth, steel is more expensive than ductile iron and the cost of pipes scale with diameter so a 60-inch diameter pipe is more expensive than a 48-inch diameter pipe.

After six months of back and forth between MTA CC managers and NYC DEP managers, the head of MTA CC and the head of NYC DEP met and agreed that the MTA would only replace the 48-inch diameter cast-iron pipe at 83rd

[33] While final designs were signed off on prior to tendering contracts, agencies and utilities updated requirements, shared new drawings, etc. after contracts were finalized. Con Ed also requested multiple changes to this contract after it had been tendered. One contractor we interviewed explained it plainly, "Con Ed is the worst, but there's really nothing you can do about it" (Personal Interview J 2022).

[34] Technically, contractors are only entitled to time claims when the MTA delays construction itself. Delays imposed by utility companies and city agencies are supposed to be factored into the contract price. While this may sound reasonable on paper, contractors still try to claw back these costs through claims and other means.

Street with a 48-inch diameter ductile-iron pipe and redesign the utility plan at the northern shaft to avoid replacing it (Personal Interview L 2022).[35] Even though the MTA didn't accede to all of NYC DEP's demands, it still bought and installed a replacement 48-inch diameter ductile-iron pipe, purchased additional lengths of pipe per NYC DEP's request in the event more pipes needed to be replaced, had its designers redesign the utility plan, and executed multiple contract modifications to compensate the contractor for additional work and impact costs.

This brief example highlights four main utility-related challenges that drive costs: first, the MTA put together a $34 million 19-month contract package that included precise utility designs and the cost of replacing utilities. Once NYC DEP reopened that process, after the contract had been finalized, it meant the MTA had to issue change orders to both the contractor executing the work and the designers who designed the utility plan. Second, and this is a more relevant and more abstract finding, the difficulty coordinating with NYC DEP led to the MTA eliminating the replacement of the 48-inch diameter pipe in the northern shaft. Without arguing the merits of the new design, the MTA had to do its design work twice, at a minimum, and delay construction while it came to terms with NYC DEP.[36] Rather than taking 19-months and spending $34 million, this contract ended up with a smaller scope, but still took nearly 50% longer to complete, 28 months, and cost close to 20% more than the initial budget, $40.5 million. Early on in our interviews with people who worked on Phase 1, we were told that "you're never not going to be in a situation where you are going to be challenged continuously" (Personal Interview H 2021). Thus, the MTA opted for a design program that minimized interactions with utilities to minimize those challenges. This meant that stations and running tunnels had to be deeper than traditional New York City subway stations, even though they would eventually connect with shallower tunnels at 99th Street. Third, when labor costs are high, costs increase as more labor, both direct and indirect, is needed to complete redesign work or extend the construction period by replacing more pipes. Fourth, this back and forth between MTA CC and NYC DEP wasn't resolved until the two agency leaders hashed out their differences directly. Stronger leadership from a governor or mayor, better communication at the staff level to resolve disputes, unambiguous standards regarding replacements, or legislation holding agencies and utilities accountable for impact costs could have avoided these delays and added costs.

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[35] There were other DEP related utility relocations negotiated in the overall contract.

[36] We assume the MTA had its designers redesign this utility more than twice because it is likely that the MTA went through a redesign including a 60-inch diameter pipe, too.

New standards, new costs

The designs and policies governing New York City's streets changed between the start of construction in 2007 and the start of revenue service in 2017. In 2008, the NYC DOT announced it would launch Select Bus Service along First and Second Avenues in 2010 (New York City Department of Transportation n.d.a). The launch of this new service was accompanied by new designs such as painted bus lanes, concrete bus pads, and electrical work embedded in the sidewalk to power ticket machines, bus shelters, and information boards (Figure 7).[37] In 2009, NYC DOT began testing new LED street lights. According to the agency (n.d.b, p.12), the average cost of a standard cobra head street light fixture, the light fixture that dotted the corridor before construction, was $160. The new LED fixtures, the one that replaced the cobra head, had an average cost of between $1,050 and $1,650. In 2012, the NYC DOT announced it would install protected bicycle lanes along First and Second Avenues (Federal Transit Administration 2013). Again, this change necessitated roadway changes: new markings, floating curbs, bulb outs, and new traffic signals. In 2014, New York City adopted Vision Zero, yet another policy that reshaped New York's streets (City of New York n.d.). All of these changes occurred in the midst of construction, which meant the design consultant had to redesign the street restoration work that had been included in the initial station contracts to reflect NYC DOT, NYC DEP, and NYC Parks requirements, and the contractors had to replace trees, benches, street lights, fire hydrants, and streets to a new standard.[38]

In theory, signing cooperative agreements, memoranda of understanding, and other documents that lock in replacement agreements with city agencies and utilities should insulate the MTA from unanticipated changes. Our review of these documents in New York and elsewhere showed that these agreements often include a clause or paragraph that leaves open the possibility of change at the discretion of the third party. When we asked why it was so difficult to lock down an ironclad master agreement with third parties during Phase 1, we were told that the project's 10-year construction timeline made it impossible for an agency like NYC DOT to freeze its street design plans during subway construction (Personal Interview L 2022). Another senior level agency official explained that there have been attempts to develop those kinds of agreements, but because agencies and the MTA interact across so many projects beyond Second Avenue, it is difficult to find common ground across each one, which ends up

[37] A concrete bus pad is a rectangular, durable strip of concrete designed to withstand the greater heat and weight of buses at a bus stop.

[38] As noted in the previous section, the decision to redesign the streets allowed the MTA to move one of the 72nd Street Station entrances from 301 East 69th Street to a sidewalk location because of the addition of the bicycle lane and wider sidewalks. Presumably this should provide similar opportunities to use the sidewalk for entrances in future phases.

derailing the process (Personal Interview N 2022). Others explained that personnel turnover at agencies and at the MTA meant that even though one person or group agreed to something, new leadership at an agency wanted new deals and finding the right staff member posed a challenge (Personal Interview O 2022; Personal Interview P 2022). NYC DEP, for instance, had at least six commissioners between the start of planning and Phase 1 reaching substantial completion (Personal Correspondence B 2022).[39]

Figure 6. Street design improvements: before and after SAS, corner of 86th street and 2nd avenue

3.2 Labor wages and staffing

When American railroad construction began in the first half of the 19th Century, labor costs were high relative to extremely low land costs (United States Department of Labor 1830). As a result, American railroad builders traded labor-intensive tunnels and embankments for curved alignments that consumed more land but could be constructed more cheaply. In England, the economic logic was reversed: labor and capital were cheap compared to land; thus, English railroad builders minimized land costs by building the straightest routes possible, even if it meant more expensive civil works. Schivelbusch (1986, p.97) describes the differences between American and English railroad construction logic at length:

> All European observers noted how the American railroad lines proceeded by curves rather than straight lines: from the very beginning, this was the main characteristic of American railroads. As early as 1827, when the first reports of the English railroad experiments inspired the proposal for the first American railroad (the Baltimore and Ohio), one of its promoters, Minus Ward, stated that the English innovation would have to be modified to suit American conditions: among other things, he mentioned 'the necessity of departing from the transatlantic system of straight rail-roads'. In a survey report for the Baltimore

39 NYC DEP shared a list of every commissioner and the duration of his or her term with us.

> and Ohio Company, S.H. Long concluded in 1830 that the English mode of construction would be uneconomical in American circumstances. He expressed his preference for a line with numerous curves, justifying it by the observation 'that…the expense of avoiding a hill or valley, by prolongation of the route, in a manner to maintain uniformity in its vertical direction, is less than that of *cutting* and *fitting*'. (Italics in original.)

This thinking no longer applies to contemporary transit projects. Like early railroaders, we argue that costs are a key project evaluation metric. By focusing on costs, projects can be optimized around overall production per dollar spent so that the types of projects that get built in the United States are extensive enough to connect and stimulate the development of vibrant population centers and neighborhoods. This doesn't mean that costs are the only thing that matters. Our hope is that by highlighting costs and cost impacts of certain decisions, tradeoffs between scope and schedule can be better understood by the public and decision makers.

During our research, both a review of articles focusing on construction costs and interviews with project managers who staffed Phase 1 projects we were told that direct labor costs account for 40%-60% of construction costs in New York (Munfah and Nichols 2020; Personal Interview I 2021; Personal Interview E 2021; Personal Interview Q 2022; Personal Interview R 2022). When we compared the proportion of labor costs to construction costs in our Italian, Turkish, and Swedish cases, we found that labor costs comprised 19%-31% in Italy, 20% in Turkey, and 20-25% in Sweden.

Labor costs consume a greater proportion of construction costs in New York for three key reasons. First, wages in New York are higher than in other cities we have examined, even to a small extent Stockholm. Second, staffing levels for tunneling, drilling and blasting, and utility replacement all require more laborers than in cities like Madrid, Milan, Stockholm, and Istanbul. Third, external constraints and work rules all limit labor productivity; thus, each labor hour produces less TBM launch box or station cavern than in other cities we have compared against.[40] In addition to the wages paid to laborers, American consultants also receive high hourly wages, in many cases even higher than the laborers building the projects, to do design work, construction management, and studies that agencies in low-cost countries like Chile, Sweden, Norway, and Italy carry out internally or with academic support.

Part of the problem is that high wages and low productivity are spun positively. In 2009, United States Representative Carolyn Maloney, an early champion of the full-length Second Avenue Subway, trumpeted the 38,000 jobs, $2 billion in wages, and almost $7 billion in economic activity generated by Phase 1 of the Second Avenue Subway

[40] According to Goolsbee and Syverson (2023) domestic construction productivity has fallen at a rate of about one percent a year since 1970 so this is not isolated to transit construction.

and East Side Access, despite both projects being many years away from completion and realizing any of their transportation benefits (Chan 2009). Similarly, if one follows the press releases from the California High-Speed Rail Authority, one quickly sees that there is always a paragraph detailing the number of jobs created to date (California High-Speed Rail Authority 2022a; California High-Speed Rail Authority 2022b). If these infrastructure projects are viewed primarily as job creation vehicles, high costs become less relevant as the transportation benefits fade into the background.

If we make the leap that costs matter, labor costs also matter. Knowing that New York's construction labor rates are continuously the highest or among the highest in the world should either compel elected officials to re-examine the deals they have supported with trade unions, emphasize cost-saving designs that reduce the number of labor hours required to build, or examine rules that limit productivity so that New York's costs can begin to resemble those in other cities (Arcadis 2016; Arcadis 2017; Turner and Townsend 2022, Torres-Springer 2022).

Rosenthal (2017) quoted experts and reports that found that New York staffed two to three times more laborers on the TBM and more broadly up to four times as many people for underground construction than in Asia, Europe, or Australia. In our own data collection efforts from Spain, Turkey, and Italy, we found that staffing levels in New York were higher. When we compared the direct labor to staff one eight-hour shift in New York, we found that it took 46 laborers to operate and support the TBM used for Phase 1. When we sat down virtually with contractors and project managers who worked on Second Avenue Subway and East Side Access, they independently confirmed that staffing levels could have been pruned without sacrificing safety or production.

Not only did Phase 1 move three times slower than counterparts in Istanbul and Madrid when it came to digging the launch box, but also operating and supporting the TBM used more than 50% more laborers than needed. The experts we interviewed told us that instead of the 46 laborers per shift who coordinated work, operated the TBM, maintained the locker rooms above ground, transported supplies to the labor crews in the tunnel, and ran the elevator to the surface, it was possible to operate and support a TBM with 30 laborers (Personal Interview I 2021; Personal Interview J 2021; Personal Interview S 2022). One former tunnel worker we interviewed was less certain of the overall numbers in terms of operating and supporting the TBM, but was adamant that tunnel workers have a culture of working hard and competing against one another so as to "work [themselves] out of a job" (Personal Interview K 2021).

Table 2. SAS TBM staff numbers

Actual and Proposed Tunnel Boring Machine Staffing for Second Avenue Subway Phase 1

Team	Title	Number	Fully-Laden Employment Cost	Proposed Number	Fully-Laden Employment Cost of Proposed Scenario
TBM Crew	General Foreman	1	$12,103.35	1	$12,103.35
	Walking Boss	1	$12,103.35	0	---
	Journeymen	6	$62,464.86	5	$52,054.05
	Miner- Mole Nipper	1	$10,221.27	0	---
	Miner- Brakeman	2	$20,821.62	1	$10,410.81
	Electricians	2	$22,872.00	1	$11,436.00
	Operating Engineer (OE)- TBM	1	$12,103.35	1	$12,103.35
	OE- Locomotives	2	$24,206.70	2	$24,206.70
	OE- TBM Maintenance Engineer	1	$12,103.35	0	---
	OE- Main Man	1	$12,103.35	0	---
	Laborers	2	$20,056.32	2	$20,056.32
Support gang- Shaft Service Crew, Bottom, and Top crew, clean the bottom of the tunnel	Labor Foreman	1	$9,645.36	1	$9,645.36
	Laborers	2	$19,670.22	2	$19,670.22
	Miner- Superintendent	1	$11,723.85	0	---
	Miner Foreman	1	$10,951.38	0	---
	Miner Change House	1	$9,075.72	0	---
	Miner Safety	1	$9,076.02	1	$9,076.02
	Minor Top Bellman	1	$10,028.16	1	$10,028.16
	Miner Top Laborer	1	$9,835.11	1	$9,835.11
	Miner Top Nipper	1	$10,221.27	0	---
	Miner Bottom Bellman	1	$10,028.16	1	$10,028.16
	Miner Bottom Laborer	1	$10,410.81	1	$10,410.81
	Miner Bottom Dumpman	2	$20,056.32	1	$10,028.16
	Miner Bullgang Foreman	1	$10,777.35	1	$10,777.35
	Miner Bullgang Laborers	2	$20,821.62	2	$20,821.62
	OE- Crawler Crane	1	$11,723.85	1	$11,723.85
	Oiler- Crawler Crane	1	$9,076.02	0	---
	OE- Loader	1	$11,723.85	1	$11,723.85
	OE- Compressor	1	$11,723.85	0	---
	OE- Muck Conveyor	1	$11,723.85	1	$11,723.85
	OE- Master Mechanic	1	$11,723.85	0	---
	OE- Maintenance Foreman	1	$11,723.85	0	---
	Surveyor	1	$9,076.02	1	$9,076.02
	Teamsters	1	$9,076.02	1	$9,076.02
Total per Shift		**46**	**$163,684.01**	**30**	**$116,528.60**
Total		**138**	**$491,052.03**	**90**	**$349,585.80**

According to our calculations, based on the wage and supplemental benefit rates as spelled out by the Labor Law §220 Prevailing Wage Schedule (Office of the Comptroller, City of New York 2010), but not accounting for overtime, the direct fully-laden employment costs for operating and supporting the TBM for Phase 1 was $500,000 per week in 2010, or $600,000 per week in 2020 dollars.[41] When we recalculated the numbers using 30 laborers instead of 46, those costs declined to $350,000 per week, or $415,000 in 2020 dollars. Over a 16-month period, after factoring in overtime pay, the addition of 16 more laborers is more than $10 million in additional labor costs (Table 2).[42] Some of these jobs are anachronistic and the product of a work culture that developed when construction was more labor intensive, as has been pointed out by Rosenthal (2017) and the Regional Plan Association (2018), and some of these jobs, such as the master mechanic and walking boss or additional foremen and superintendents, we were told, are ways to lighten the load for older laborers who have worked in the trenches for years (Personal Interview A 2021; Personal Interview I 2021). This does not include savings coming from using less labor-intensive construction techniques.

Digging tunnels

Tunnels and subways are tied up with one another, and tunnel construction in New York has received a disproportionate amount of critical attention despite only accounting for $380 million, or 12% of Phase 1's total construction costs.[43] Additionally, from a performance standpoint, while the TBM work encountered a number of challenges at the outset, the average production rate, 15 meters per day approached the high end of expectations described in the Final EIS and was seen as a success internally (Final EIS 2004 3-7; Personal Interview C 2021; Personal Interview Q 2022).

However, the largest cost of TBM tunneling is digging the launch box to get the TBM into the ground. We spoke to three experts with access to project documents who explained that digging the 244-meter-long by 18.9-meter-

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[41] Overtime rules vary by trade, but the basic rules for tunnel workers are double time after an eight-hour day, double time for Saturdays and Sundays, and double time for specified holidays.

[42] While the initial plan for TBM operations was not to operate on the weekends, when wages are paid at double the standard rate, as the schedule slipped, weekend work was necessary, which meant labor costs increased.

[43] It should be restated that the initial tunneling contract also included starter shafts for the 72nd Street Station so that $380 million includes the majority of the tunnel work and additional excavation and utility relocation. A portion of the tunnel lining work was relocated to the 86th Street Station heavy civils contract.

wide by 19.8-meter-deep TBM launch box, two starter shafts for the 72nd Street Station, and storing and hauling muck was the largest expense. Two of the experts said that this phase of construction consumed 40-50% of the $380 million tunneling contract. The balance of the contract was spent on the two tunnels (Personal Interview A 2021; Personal Interview I 2021). It took three years to dig the launch box and 16 months to construct the tunnels, which largely explains the cost differentials. When we compared how long it took to set up TBM operations in Istanbul and Madrid, we were told that in both cities it takes one year or less instead of the three it took in New York (Personal Correspondence C 2022; Personal Correspondence D 2022).

When labor costs are high, it is critical to speed things up rather than slow them down. In addition to concerns over fragile buildings, unexpected geological conditions, and obstructions, all of which delayed construction, workers' time was spent unproductively. One senior tunneling manager explained that work-window constraints, which were spelled out in the contract, forced S3 Tunnel Constructors to dig an additional storage space and build a conveyor system to move the excavated earth to the storage area behind the launch box so that it could store the muck before loading it onto trucks during the hours hauling was permitted. This meant that instead of handling muck once and carting it out, S3 had to dig, then haul, and then haul a second time to dispose of it. It also meant that when trucks could haul muck, S3 had to hire three times as many of them as it would have had trucks been allowed to make roundtrips throughout the day. One contractor told us that because of these hauling restrictions, S3 spent an additional $20-30 million double-handling material, building an underground storage facility and conveyor system, and ramping up trucking within the approved work window, usually from 9AM to 8PM.[44] In short, this manager explained, "trucking changed our entire [tunneling] operations" (Personal Interview I 2021).

Consultants versus in-house capacity

American transit agencies rely heavily on consultants rather than in-house staff to complete planning, design, engineering, and construction management services for capital projects. As a result, American soft costs, the cost of hiring consultants, are far greater than what we have seen in our international case studies in Italy, Turkey, and Sweden.[45] The American preference for consultants and non-government employees dates back to at least the 1960s. DiIulio (2014) explains that starting in the 1960s, under the guise of making government "work better," federal agencies reduced the number of full-time employees while expanding the number of federal agencies,

[44] Overnight trucking is also much less susceptible to being upended by traffic.

[45] Consultants are used extensively in Istanbul. Wages are just much lower, even after PPP transformation.

taking on debt to pay for more services, increasing spending by five times, and ceding control of policy implementation and development to proxies, contractors and consultants, who now do the work of government. This Leviathan by Proxy model, Dilulio's term, also applies to transit agencies, where agency staff now manages grants, contracts, and the innumerable interfaces between contractors and the agency rather than planning, designing, engineering, and managing the construction of transit projects. Additionally, transit agencies take advantage of federal grants and transportation bond acts for capital projects to pay for consultants to do jobs that previously would have been done by in-house engineers and planners.

Traditionally, NYCT bucked this trend. Prior to the creation of MTA CC in 2003, NYCT had an in-house engineering and construction management group, Capital Program Management (CPM), with about 1,600 full-time employees; it performed 60% of capital-project-design work and 95% of the construction management itself (Personal Interview B 2022; Personal Interview T 2022). MTA CC, conversely, follows the Leviathan by Proxy approach outlined above. Instead of a large in-house team, MTA CC employed 124 full-time employees in December 2011, a time when it was responsible for delivering close to $20 billion worth of projects: Phase 1, the 7 Line Extension, East Side Access, and the Fulton Transit Center (Metropolitan Transportation Authority 2012; Metropolitan Transportation Authority 2019b).[46] By moving away from the CPM model of robust in-house capacity, MTA CC turned to consultants to carry out design and construction management during Phase 1 and navigate the MTA's internal processes and politics. Just as federal spending skyrocketed while the number of full-time employees shrank over the last half century, the MTA capital plan has doubled between the $27 billion (in 2020 dollars) 2010-2014 and the proposed $54.8 billion 2020-2024 plan, even though the labor-intensive CPM has given way to MTA Construction & Development, the entity that replaced MTA CC.

In the Leviathan by Proxy model, the federal government got neither better nor smarter by trading full-time government employees for consultants. Instead, the federal government fragmented and sprawled as more proxies needed to be managed and audited, new programs and grants needed to be administered, new procedures and guidelines governing new work flows needed to be created, and intra- and inter-agency demands needed to be integrated into this approach to public administration. For MTA CC, it was tasked with coordinating with design contractors, construction management consultants, general contractors, city agencies, and dozens of NYCT user groups, such as signal maintainers and train operators.

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[46] It is important to recognize that by the 2000s, CPM, became more reliant on Indefinite Quantity contracts, consultants, to design and manage its projects as nearly 50% of CPM's technical staff approached retirement age (Personal Interview U 2022).

A review of detailed work modifications shared with us show that managing these interfaces between NYCT and Phase 1 designers meant that MTA CC had to instruct and pay its designers millions of additional dollars to redesign turnstiles after specifications changed, lay out new floor-tiling plans because NYCT objected to the proposed tiles' dimensions, add internal partitions to public toilets, relocate CCTV locations, and revise the fire alarm system. Since NYCT had exacting standards, perhaps with new, experienced leadership who had a track record of planning, designing, and managing a megaproject, it could have designed the extension it wanted while also maintaining the project's scope, schedule, and budget.

While there is an accounting logic to eliminating the ongoing operating expenses and long-term liabilities of full-time employees, international best practice recommends a different approach. Dilulio is quick to point out that in his research, the English, French, Japanese, German, and most other democracies he surveyed place more restrictions on what governmental work can be contracted out than in the United States. In our Italian and Swedish case studies and in work we have done on Spanish and French projects, all countries with medium and low costs, we see agencies retain greater control of projects by doing early planning and design, procurement, and construction management themselves rather than hiring consultants (Maynar 2003; Eno Center 2022). By doing this work themselves, these agencies spend less on consultants than American agencies and are better equipped to maintain control over projects rather than being led by consultants.

During Phase 1, the MTA spent $656 million on consultants to design and engineer the full-length Second Avenue Subway and support and manage Phase 1 construction.[47] Thus soft costs were 21% of Phase 1's $3.16 billion hard costs. Phase 1's soft costs compare favorably to other domestic projects where in-house teams are smaller and less experienced. Projects like Los Angeles Metro's Regional Connector and Purple Line Extension projects and the MBTA's Green Line Extension have all seen their soft costs exceed 25-30% of hard costs. In our international research and case studies, we found that Italian soft costs are only 10% of hard costs, and French, Spanish, and Turkish ones are 5-10%.

This large difference between international and domestic soft costs is all the more alarming because American hard costs tend to be greater, too. It makes sense that soft costs scale with hard costs. As we detail below, Phase 1 stations are larger than those in our other cases, and this raises the hard costs but also the costs of design and construction management; we expect that if stations are right-sized in the future, then design costs will shrink

[47] When you combine similar costs from East Side Access, Fulton Transit Center, and the 7 Extension, more than $2 billion has been spent on design, planning, engineering, and construction management consultants (MTA 2019)

proportionately. However, not all hard costs work like this. In particular, if there is overstaffing in the tunnel and if wages are higher than normal, then it has no impact on the design costs, which do not include these workers' supervisors or their benefits.

The upshot is that reducing the share of craft labor in the overall cost is independent of cuts in the share of soft costs, unlike the case for other items such as station costs. In our closest-wage comparison case, Stockholm's Citybanan, labor was 23% of the contract cost, compared with about 50% in New York, both figures including white-collar workers (such as utility supervisors in the Second Avenue Subway tunnels). Shrinking the labor share from 50% to 25% while keeping the non-labor costs constant involves, in effect, transitioning from spending $75 on labor and $75 on everything else to spending $25 on labor and $75 on everything else; this is a factor of 1.5 reduction in hard costs, without any effect on soft costs. Thus, the management and engineering costs are really 31% over the base hard cost with labor at a globally normal rate.

The large premium of design and engineering costs has to be understood in terms of consultant finances. Among people we have interviewed in the corporate world, the commonly cited figure is that hiring management consultants means paying triple the amount one would pay if it were done in-house. People we have spoken with in the consulting industry have likewise told us that their employer charges about three times their actual wage for their time. This factor of three figure needs to be tempered by the issue of overheads and worker benefits, but private-sector white-collar norms are that overheads and benefits add about 30% to the cost of a worker, rather than the 100% premium more common in unionized public-sector jobs with extensive pension agreements.

Now just because a consultant or an army of them has been retained, managing and utilizing them effectively requires expertise and knowing what one wants, especially when things deviate from the plan. According to our interviews with former MTA employees and consultants who worked for the MTA, consultants, like construction labor, were overstaffed and not always used in the most efficient manner. Without a developed in-house team to fall back on during construction, every wrinkle, from redesigning the 72nd Street cavern to studying the fragile buildings along the construction zone to retooling the construction packages, re-estimating costs, and developing smoke mitigation for blasting, required pressing the consultants into service beyond their contractual agreements. The AECOM-Arup design, engineer, and construction support contract began as a $187 million contract, but with a planned $143 million option picked up and unanticipated contract modifications, it grew to a 210-month $452 million behemoth. The WSP contractor construction manager contract began as a 91-month $80.9 million contract and grew to a 173.5 month $204 million one. When we examined cost overruns for these kinds of contracts in

Turkey and Italy, we found that they also often run over budget and schedule because of unexpected challenges and delays.

The benefits of the consultants were clear. First, they could be scaled up and down much more quickly and precisely, in theory, than MTA CC. Second, they completed specialized work, from redesigning the 72nd Street cavern to conducting air quality monitoring to carrying out public outreach. Third, they helped MTA CC navigate delicate relationships with other agencies within the MTA, namely NYCT. On this last point, a number of people told us that MTA CC had a difficult time wrangling NYCT even with its consultants, but without the consultants it would have been impossible.[48] Based on our review of documents and interviews with consultants, we have found that architects, planners, and engineers working on Second Avenue Subway billed the MTA between $75 and $310 an hour in 2011, or $86 to $357 in 2020 dollars, including hourly wages, overheads, and the consultant's fixed fee.

The drawbacks of the consultants were also obvious. First, MTA CC clung to the consultants "like a security blanket" (Personal Interview L 2021). Whenever there was a question, uncertainty, or problem, project managers asked the consultants to study it. One former MTA CC manager explained to us that the agency leaned on its consultants, perhaps too much, in part because there was a perception that the consultants were "an endless resource to study everything… but how many different iterations of a transformer do you need to see [before making a decision]" (Personal Interview H 2021)? When it came time to redesign the construction contract packages, the consultants looked at every option between 6 and 29 contracts (Personal Interview E 2021; Personal Interview H 2021). Having a consultant on call meant that any request could be entertained and give cover to delaying a decision, a problem we saw in our GLX case, too.[49] Second, several consultants who worked on Phase 1 told us that the lack of internal capacity and a clear sense of what the agency wanted meant that consultants wasted time solving basic problems that should have been determined prior to hiring a consultant (Personal Interview F 2021; Personal Interview V 2022; Personal Interview W 2022). Specifically, we were told that instead of being handed design guidelines at the start of the project, it was the consultants who developed those guidelines first, sometimes in conflict with NYCT

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[48] It should be noted that this issue of fraught intra-agency communication is a feature of the Leviathan by Proxy approach. Without consultants, perhaps, the agencies could work together to resolve differences rather than allow consultants to sit between them and conduct additional studies.

[49] The endless studies and consultant work is a feature of the Leviathan by Proxy model described earlier. When managers within an agency aren't empowered to make decisions, consultants become a necessary stamp of approval. Unfortunately, this also means that the agency staff itself likely does not have the appropriate experts to tell the consultants what to do.

standards (Personal Interview W 2022).[50] This is especially surprising since the MTA had completed new station construction projects in the late 1980s. Third, the MTA developed a four-phase plan for delivering a full-length Second Avenue Subway. With Phase 1 complete, knowledge and lessons learned from Phase 1 have been retained by the consultant teams, and many of the most experienced managers from Phase 1 who learned by doing have left the agency, some have retired and others now work in the private sector. An agency staffer at another large North American agency we spoke to about its reliance on consultants explained that at her agency, it was the consultants who knew everything about past projects rather than agency staff (Personal Interview M 2021).

3.3 Procurement and risk

Procurement costs cannot be neatly separated as line items, since they affect the costs of many individual items, some direct rather than indirect. Nonetheless, a picture emerges in which the totality of the procurement system used in New York doubles the overall costs of major MTA infrastructure projects.

Traditionally, procurement in the United States has been done using design-bid-build, including Phase 1 of the Second Avenue Subway. Design-bid-build stresses the separation of design and construction, with strong public-sector input in the planning and design phases. As we saw above with the transition to the Leviathan by Proxy mode of public administration, design-bid-build runs counter to its key tenets, namely contracting out and ceding control to consultants. As such, it is no surprise that as transit agencies have reduced headcounts and hired teams of consultants to plan, design, engineer, and manage construction, design-bid-build has lost popularity, as methods that give more control to contractors and consultants by merging the design and construction contracts into one, called design-build, have gained popularity. Managers we have spoken to at the MTA express mixed opinions about design-build, some say it is reducing costs for Phase 2 and others the opposite (Personal Interview H 2021; Personal Interview B 2021).

Design-build is being pursued because the recent American experience with design-bid-build has not been positive. In our interviews, we were told repeatedly that design-bid-build is too adversarial; the GLX case details the same criticism, leading to the adoption of Construction Manager/General Contractor and more recently design-build, as in New York and other American cities. A consultant who worked on the 7 Extension and East Side Access told us that design-bid-build gives the agency more control via its construction management consultants to direct

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[50] These same consultants said that this problem arose at transit agencies across the country.

contractors down to telling them what materials to use (Personal Interview N 2021). This retained control, however, leads to conflict between the agency and the contractors and the design and construction contractors.

Design-build has not resolved these problems. Agencies still want to be able to exert control over projects and contractors, sometimes this is done through an owner's representative, a third-party private firm that is hired to do design review, by requesting changes or establishing precise, though perhaps inappropriate, design specifications.

The real issue regardless of whether the MTA uses design-bid-build or design-build is risk allocation. The more risk the private contractor is required to bear, be it geological or schedule risk, the higher the bids are (Ryan 2020; Personal Interview N 2021; Personal Interview O 2021; Personal Interview W 2022). The MTA has six mechanisms that impose an unusual extent of risk on the private contractors, which we detail below.

First, the bids involve extensive use of private information. The MTA has independent cost estimates that it uses to benchmark private bids, but those are held from the public as trade secrets, so the bidders have to produce their own estimates when preparing their bids.[51] The only itemized costs that are transparent are those of labor, which are subject to collective bargaining and published for both wages and benefits. This contrasts with the transparent itemized costs in low-cost countries like Italy, in which the private bidders get to see the internal estimates and work from them.

Second, contracts are not itemized, but are instead let as lump sum. The contractors prefer this system, since they get paid faster under lump sum and have less paperwork to do, though contractors we have spoken to have complained that working with American transit agencies is time and labor intensive (Personal Interview N 2021; Personal Interview X 2022). However, when changes are required, there is no prior schedule for establishing how to cost them, and sometimes, conflict between the MTA and the contractors is resolved through costly litigation.

Third, the MTA puts the onus of underground geotechnical risk on the contractors. This is unusually risky because of the unpredictability and poor records of underground utilities in New York. TBMs require continuous maintenance, which adds down time to the project during which tunneling workers still have to be paid; both an S3 manager and a Turkish contractor with a history of low-cost intercity rail tunneling estimate that TBM uptime

[51] The New York State Department of Transportation, conversely, does publish itemized unit cost prices. We have been told this is a common practice among state departments of transportation.

varies from 25%-40% (Personal Interview I 2021; Personal Interview Y 2022). Between inevitable geotechnical risk and what contractors view as capricious MTA requirements, contractors hedge against all risk by bidding higher.

Fourth, state regulations are heavy-handed whenever costs run over prior estimates. The Cuomo administration added a debarment rule blacklisting contractors whose final costs go 10% above their bids. In a letter to the MTA Board, the Citizens Budget Commission (2019) argued that the threat of debarment reduced competition because contractors were afraid to submit bids on MTA projects and risk being banned from bidding on future New York State contracts. One source at the MTA compared the threat of debarment as the state pointing a gun at contractors, for which they respond with a bazooka, bidding anything from 15% to 40% higher, the latter including all risks (Personal Interview O 2021).

Fifth, early planning includes large contingencies to account for unanticipated delays, design changes, or increases in unit costs. For example, the ongoing MTA accessibility mandate is costed at $70 million per station, but this is really $50 million per station plus a large risk factor. Once contingency is in the budget, the money will be spent; there is always some local demand, betterment, or related project that could use the money, for example see the description of back-of-house space in the stations section below, and the soft cost is thus converted to a hard cost.

Sixth and finally, in New York, conflict between the MTA or other transit agencies and the utilities is endemic. Utilities do not cooperate with the MTA, and do not properly document underground infrastructure (Personal Interview N 2021; Personal Interview O 2021; Personal Interview I 2021). For example, electric cable relaying is planned to coincide with alternate street parking rules, but some car owners forget to move their cars, and then Con Ed lays the cable around the parked car, which may not be marked on a map at all (Personal Interview 2019). At the NYC DEP, even more cooperative managers cannot get an up-to-date map of the water and sewer mains from planners and middle managers, who are used to withholding information. A project begun in the late 1990s to map the underground stalled after the 9/11 attacks, when the mood turned toward secrecy and agency officials justified their decisions on grounds of national security (Milner 2017). This leads to high costs but also high uncertainty in costs: even installing an elevator at an above-ground station may run into utilities conflict while the contractor digs up the sidewalk to lay foundations.

Risk is a two-sided affair, and the MTA has long attempted to reduce its exposure to cost overruns. This has evolved into detailed specifications, under design-bid-build and design-build procurements, in which the agency determines which materials to use and is inflexible about changes based on the inevitable geotechnical surprises that happen during underground construction. This has the triple effect of increasing overall costs to the contractor, increasing risk, and reducing the number of contractors available to do business with the MTA.

The result, in part, is that this limits competition among contractors because only those with enough experience or financial resources are willing to work under these conditions. The station and tunnels contract for the 7 extension was a one-bid contract, and the TBM tunnels contract for Phase 1 only had two bidders. The most competitive Second Avenue Subway contracts were those that came in at the depth of the Great Recession, when contractors could not get private-sector work and therefore competed for public-sector jobs, leading to below-estimate bids. Even then, contractors and current and former MTA employees told us that client-contractor relations raise costs because of "the MTA factor," which has parallels in other American transit agencies.

When contractors are pushed away due to the mutually hostile relationship with the MTA, the few that are left can charge a hefty premium for their work. We were told that the profit rate for Second Avenue Subway Phase 1 was 5-20% on MTA contracts, between risk compensation and the small pool of available bidders (Personal Interview O 2021; Personal Interview I 2021).

3.4 Station design

The station contracts are Phase 1's largest cost center. After summing the eight station contracts, we see that $2.44 billion of the $3.16 billion in total construction costs, or 77%, was spent on the four stations.[52] Now because these contracts are not disaggregated and some elements like ancillary facilities span multiple contracts, it's impossible to pull out and compare specific elements. This is one of the challenges of lump sum contracts, a practice we discourage. Without an ability to scrutinize itemized costs it is difficult to know exactly where the money is going, which, in turn, makes it difficult to learn from projects and reduce costs in the future.

Station designers, some of whom worked on Second Avenue, told us that in general, stations should be standardized boxes that are only customized enough to fit into unique settings. Underground stations require greater customization than above-ground stations because of the challenges of finding suitable surface-level entrances and exits and shafts for ventilation. In a crowded city where there aren't open expanses, properties have to be acquired. In cities like Copenhagen, London, Naples, Istanbul, and Rome, which are old and built up, the development of new subways catalyzed the creation of plazas and pedestrian spaces designed to reclaim the public realm from

[52] This is not entirely accurate. The $378 million TBM contract also included two starter shafts for the 72nd Street Station. Presumably the costs of those shafts were similar to the $40.6 million 86th Street Station contract that specified the same kind of work. The $336.5 million systems contract included work within the stations. Finally, additional third-party costs that were not paid directly to the contractors, and thus not included in the station contracts, totaled another $110 million.

vehicular traffic and make it easier to site a station, stage construction, store materials, and adopt more standardized station designs. In New York, NYC DOT mandated that the MTA maintain four lanes of traffic throughout construction and no new plazas or pedestrian spaces were created in former rights of way for automobiles, though new bicycle and bus lanes were added by NYC DOT. Because of the inflexibility of New York's built environment and the policies that regulate it, it was impossible to standardize the three newly built stations and apply lessons learned from one station to the next. The 72nd Street, 86th Street, and 96th Street Stations differ from each other in terms of overall length, depth, construction techniques, location of ancillary facilities, finishes, number of elevators and escalators, crossovers, and the amount of back-of-house space for technical rooms and rooms for different NYCT user groups that operate and maintain the subway (Table 3).[53]

The three new stations are underground cathedrals measuring 305, 400, and 490 meters long with full-length mezzanines above the platform level and two above ground ancillary facilities for air tempering and ventilation (Figure 8). The station platforms measure 187 meters long. These three new stations have station-box lengths that are between 60% and 160% longer than the platforms and back-of-house areas that are between 150% and 260% larger than the passenger areas (Figure 9). In our Italian case, we found that Rome's MB and MC station boxes were 3% to 47% longer than their platforms. In our Sweden case, we found that the station box for Odenplan in Stockholm is 250 meters long and the trains are 214 meters, an extra 17%. In our Istanbul case, we found that the current thinking is that rather than building one station box, the latest designs for M3 Phase 3, which is a heavy rail line with 180 meter long platforms, is to build smaller cut-and-cover boxes down to the mezzanine level and connect them to the platform via escalator tubes; thus, the station boxes are shorter than the platforms.[54] Back-of-house space, such as technical rooms and staff changing rooms are a level above the mezzanine while tunnel ventilation and drainage rooms are located between the platforms (Figure 10). The result is smaller excavations, which have grown even smaller over time without sacrificing ridership capacity. We underscore this difference to

[53] Back-of-house space is the area in a station that is dedicated to New York City Transit staff rather than passengers. These spaces include storage rooms, offices, work spaces, mechanical rooms, etc.

[54] This is not a comprehensive examination of descriptive station data. In general, this data is not publicly available, often seems unreliable, and is difficult to access. We use these examples as an illustration to show that based on the data we have seen and trust, New York's station lengths and volumes are far larger than anything else we have found.

show that Phase 1's stations are uniquely large relative to their platform lengths and that this design decision contrasts sharply with stations in lower-cost countries.[55]

Table 3. Phase 1 Station statistics

Station		96th Street	86th Street	72nd Street	63rd Street
Length	feet meters	1,591 485	969 295	1,305 398	1,140 347
Width	feet meters	57 17	64 20	64 20	58 18
Depth*	feet meters	54 16	84 26	100 30	129 39
Platform Length	feet meters	615 187	615 187	615 187	615 187
Platform Width	feet meters	30 9	30 9	30 9	30 9
Back-of-House Space**	square feet square meters	95,553 8,877	76,535 7,110	59,760 5,552	71,736*** 6,664***
Customer Space	square feet square meters	36,776 3,417	39,994 3,716	38,797 3,604	5,304**** 493****
Escalators		9	13	10	12
Elevators		2	2	7	7
Entrances		3	2	3	
Costs	millions	837	656	812**	246
Excavation	cubic yard cubic meter	316,382 241,891	172,500 131,886	190,358 145,539	
Million $/cubic meter		3,460.2	4,974	5,579.3	

* Depth is street level to running track

** Back-of-House-Space doesn't include ancillaries

*** Excluding existing station area, 63rd Street added 5 new elevators; total back-of-house is 82,296 square feet and total customer space is 28,094 square feet

**** 72nd Street station shafts are not reflected in these costs

[55] In our attempts to gather this information, we believe that stations in China have large back-of-house spaces more akin to what we find in New York.

72nd st. North: Laverick, K., https://www.vanshnookenraggen.com; 72nd st. South: Goldwyn, E.; 86th st. North: Henderson, J., https://www.wikiwand.com; 86th st. South and 96th st. South: Walsh, K., Forgotten New York.; 96th st. North: Google Street View.

Figure 7. Ancillary facilities

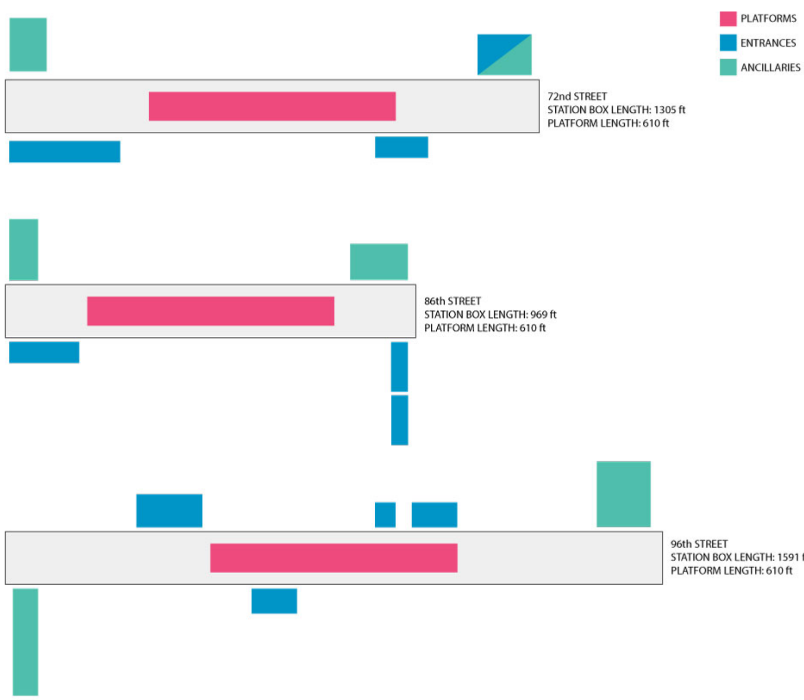

Figure 8. Phase 1 station vs. platform lengths

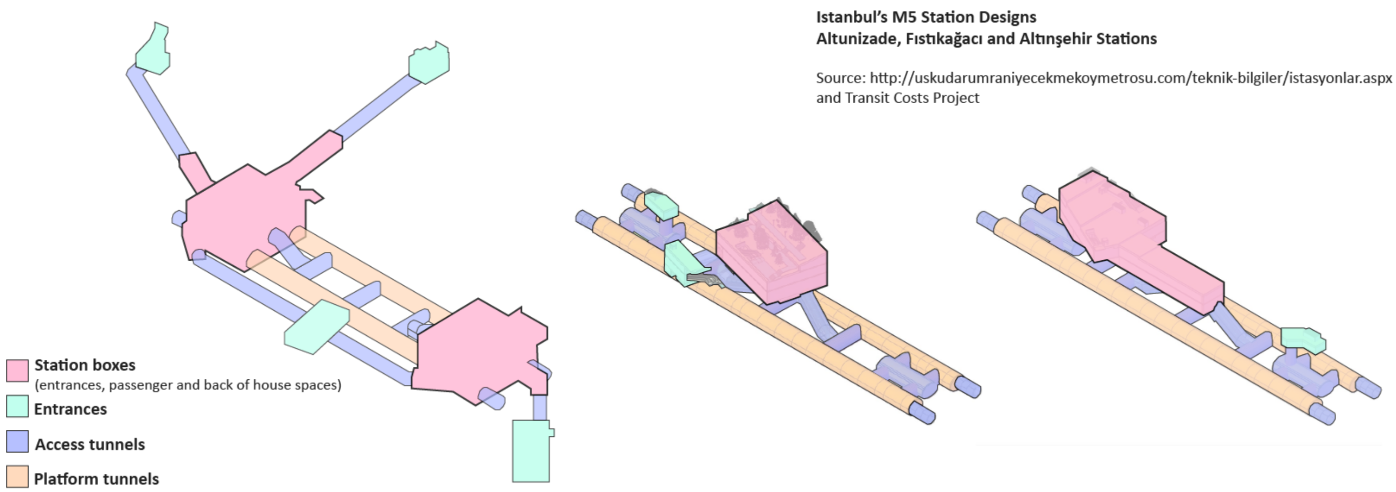

Figure 9. Istanbul M5's station design

Phase 1's stations extend so far beyond the platforms because of the addition of extensive back-of-house space for NYCT user groups and the introduction of new ventilation and air tempering systems. In multiple interviews with high-ranking officials from NYCT, MTA CC, and different consultants involved with station design, we were told that NYCT lobbied for more back-of-house space at every opportunity. One former NYCT head told us that "Back-of-house space is important. You can never have enough of it…. If you don't get it during construction, you're never going to get it" (Personal Interview G 2022). There are two important pieces of context unstated in this quote. First, NYCT didn't pay for Phase 1. Since MTA CC was in charge of delivering the project, it was tasked with managing scope, schedule, and budget. A former senior MTA CC official told us that because NYCT was MTA CC's client, NYCT made requests of MTA CC and had the power to withhold its approvals if it didn't get what it wanted (Personal Interview K 2022). Since NYCT's budget wasn't at risk, it asked for the moon, just as NYC DEP wanted larger pipes and NYC Parks wanted money for additional park employees, and received independent rooms for each user group.[56] Further frustrating any attempt to control costs, MTA CC lacked the stature to push back on NYCT's requests forcefully. Contractors and former MTA employees acknowledged that NYCT employees routinely disrespected MTA CC in meetings (Personal Interview J 2022; Personal Interview W 2022).

[56] It is worth noting that conceptual designs included in the Supplemental EIS for Phase 2 combine some of these spaces rather than giving every group its own room.

Second, though not stated outright in the quote, there was a perception that existing stations lacked adequate space for different NYCT user groups; thus, this was an opportunity to ensure that there would be enough offices, changing rooms, and storage facilities in these new stations. Whether or not this was strictly true is debatable. One former MTA employee told us that during a space audit in the 1990s, a number of unassigned rooms had either been claimed informally by different user groups or had been completely forgotten by time (Personal Interview U 2022).

So how much back-of-house space is even necessary? One design and engineer consultant who worked on Phase 1 asked us, “Why do you need lighting storage at every station? Why can’t the hydraulic guy and track guy share a room?” (Personal Interview C 2022). We were told that each user group needs its own room because each user group bears responsibility for cleaning and maintaining its own room; thus, how would those responsibilities be distributed if multiple groups shared a room (Personal Interview E 2022)? As unsatisfying as this answer is, it suggests that this issue can be resolved if there’s a desire to resolve it. In fact, early renderings for Phase 2 suggest that back-of-house rooms will be consolidated. The next question becomes why do all of these spaces have to be underground where construction is most expensive? Paris’s Line 14 extension includes stations with surface technical rooms surpassing 3,000 square meters (Personal Correspondence E 2022).

Beyond these general cost and space drivers, each station has unique characteristics that increase costs. 96th Street, the largest of the three new stations, is longer than the Empire State Building is tall for three specific reasons. First, bedrock runs relatively close to the surface along the majority of Phase 1’s alignment, which is why a hard-rock TBM was selected for Phase 1. North of 92nd Street, however, the bedrock slopes down 60 meters from the surface, leaving a layer of varved silts and clays extending down from the surface. This transition from hard rock to softer earth meant that a hard-rock TBM worked best if it went directly into the hard, abrasive Manhattan Schist at 92nd Street. Second, in order to take advantage of the pre-existing tunnel extending north of 99th Street, a connection had to be made between where the TBM went in and 99th Street. Third, the 96th Street Station is currently the terminal station for the Broadway Line. According to our interviews, terminal stations, in general, are larger because they require more back-of-house space to accommodate greater staff needs and crossover tracks to ease train operations.[57]

[57] By building in phases, the terminal stations for the Second Avenue subway shift with each phase, though the northern terminal will be fixed by the completion of Phase 2.

72nd and 86th Streets differ from 96th Street in how they were constructed: deep mining. Nearly all subways globally use cut-and-cover stations, underneath wide city streets or parks or other open spaces in more constrained city neighborhoods. No such constraints exist on the Upper East Side: Second Avenue is 30 meters wide, and in the early 20th century the forerunners of the MTA built four-track cut-and-cover stations under such avenues. 72nd and 86th Streets were not built this way: instead, the MTA dug small shafts and used them to blast the cavernous halls described above.

Deep mined stations have a clear impact on costs. Wickens (2020) observed this relationship between greater costs and deeper stations when he detailed growing costs in Toronto. When we examined the characteristics of the three new stations in New York, we saw differences in the number of entrances, escalators, and elevators, all of which affect costs. In general, we see similarities in space dedicated to passengers, roughly 3,600 square meters per station. Back-of-house space, spaces dedicated to non-passenger needs like mechanical rooms for elevators and escalators and NYCT user groups, on the other hand, varies greatly at each station, ranging from 5,500 to 8,900 square meters per station.[58] According to the MTA's (2019) Mega Projects dashboard, which reports costs as of 2019, we see that the 96th Street Station cost $837 million, the 86th Street Station cost $656 million, and the 72nd Street Station cost $812 million. When we control for station volume, based on the excavations for each station, we see that 96th Street cost $3,460 per cubic meter, 86th Street cost $4,974 per cubic meter, and 72nd Street cost $5,579 per cubic meter (Table 3). Thus, on a per cubic meter basis, 96th Street has the lowest per volume costs, and the 72nd Street Station has the highest. Thus, 72nd Street is 61% more expensive than 96th Street on a per cubic meter basis and 86th is 44% more expensive than 96th Street. Since 72nd and 86th Street were constructed using the same technique, we expect their costs to be relatively similar. The main differences between those stations after controlling for volume is in the number of station entrances, two versus three, and elevators, two versus six.[59]

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[58] 96th Street, as mentioned earlier, is uniquely large because of geology and need to connect to existing running tunnels at 99th Street. Despite this caveat, the back-of-house spaces at 72nd and 86th Streets are still substantially larger than the passenger spaces.

[59] We were told in an interview with a former CEO of the MTA that Second Avenue Subway Phase 1 entrances cost $100 million each (Personal Interview Q 2021). No one else ever confirmed that number so it's hard to know how accurate it is, but we assume a former MTA CEO would be well informed about these issues. If we deduct $100 million from 72nd Street's total costs, the costs per cubic meter decline from $5,579 to $4,892, which is 1.65% less than 86th Street's $4,974 per cubic meter costs, or, they are roughly identical.

4 Conclusion

Costs are soaring throughout the English-speaking world. There is mounting evidence from Seattle, Los Angeles, Toronto, Sydney, Singapore, Hong Kong, Melbourne, and the Bay Area that the cost of rapid rail projects in the United States and other English-speaking countries is going to exceed $1 billion per kilometer even outside of New York. The best way to address these soaring costs is to empower experts at transit and capital construction agencies to plan, design, and manage the construction of these projects rather than relying on agency staff to manage contracts, grants, and the interfaces between consultants and agency departments. We argue that by elevating the transit agencies' authority, and this unequivocally means bringing in experts who have a track record of delivering megaprojects at reasonable costs, this will temper downstream cost drivers.

Based on our research in New York, Phase 1 costs are so much greater than other projects in our database because the MTA struggled to manage intergovernmental and utility coordination, achieve cost savings in labor wages and staffing, increase contractor competition by making bidders take on all of the risks associated with underground construction, and reject expensive station designs that differ from what we have found in our lower cost case studies. In each instance, the MTA paid more than agencies in Italy, Sweden, or Turkey because it was unable to secure agreements with NYC Parks, Con Ed, or NYC DOT without agreeing to millions of dollars in mitigations, staff construction according to international standards, share risk more equitably with its contractors, or say no to NYCT's excessive back-of-house space demands.

Phase 1 remains an important project that delivered enormous benefits to New Yorkers. Our worry, however, is that because costs continue to rise, it is only the projects with the largest benefits, like Phase 1, that are worth the enormous costs and political fights to pay for them. By tackling the issues outlined above, we believe that projects across the city that previously looked too expensive to build will become achievable, from the Interborough Express to the decades-promised extensions along Nostrand and Utica Avenues in southeastern Brooklyn to fartherout plans like a 6 extension to Co-Op City in the Bronx and a 7 extension to Whitestone in Queens. The key, however, is to reduce costs so that building more projects is politically feasible rather than turning to creative financing mechanisms like public-private partnerships or value capture.[60]

There's widespread agreement in New York that investment in the subway is an important political goal. The limiting factor is always money. A New York that keeps building at today's extreme costs is one in which Phase 2 or the Gateway tunnel is a massive generational project, requiring calling in every favor to get funding. A New York that addresses its construction cost crisis and increases its efficiency to what we see in low- or even medium-cost countries is one in which both of these projects are affordable and even the extra projects we mention above are viable alongside many more.

[60] We aren't uniformly dismissing alternative financing mechanisms, but first we need to bring down costs before tapping additional pools of money.

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