BOSTON BLUE LINE

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November 22, 2024
Mr. John Roma
Construction Industries of Massachusetts
1500 Boston Providence Hwy # 14,
Norwood, MA 02062

Re: Boston Blue Line Extension Project- Final Report

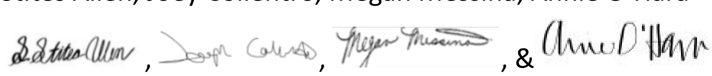
Dear Mr. Roma:

University of Vermont Capstone students were provided with information regarding designing a replacement for the Boston Blue Line Extension Project. This report contains the compiled work our group has completed this semester. The purpose is to design an earth retention system for the potential train station for the new Blue Line stop at the Hynes Convention Center.

Thank you for providing this opportunity for us to serve your community.

Best Regards,

Stites Allen, Joey Collentro, Megan Messina, Annie O'Hara



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EXECUTIVE SUMMARY

This project addresses the need for a new train station as part of the Boston Blue Line Extension from Government Center to Hynes Convention Center. The primary challenges involve designing a cost-effective and efficient earth retention system capable of supporting deep excavation while minimizing disruption to nearby businesses, residents, and historical structures.

Key constraints considered during the design process include construction time and disruption, user accessibility, design requirements, long-term maintenance costs, and sustainability. Four main alternatives were evaluated: concrete diaphragm wall (slurry wall), sheet pile wall, secant pile wall, and a "no change" approach. Each option was analyzed based on construction time and disruption, cost, structural performance, and water retention.

Our final recommended solution is the concrete diaphragm wall. This method offers superior groundwater retention, minimal construction vibration, and excellent structural stability, all while serving as a permanent part of the station. Additionally, the slurry wall supports sustainability by reusing fill material, employing local contractors familiar with Boston's unique soil conditions, and ensuring long-term efficiency with reduced maintenance costs. This solution was chosen because it best meets the project's requirements, effectively balancing groundwater retention, minimized soil disruption, and structural stability, making it the most suitable choice for the new train station at Hynes Convention Center.

Limitations

This design report represents work performed within a limited time, with limited resources, by students. This work was supported and overseen by our faculty and advisors, as applicable. This support and oversight were for guiding our student work in an academic setting, where emphasis is on learning about the process of engineering practice and is different than for work produced to a client by a professional engineering organization. Therefore, you are advised that before fully relying on any elements of this report and design, the recommendations and designs need to be independently reviewed by a qualified Licensed Professional Engineer.

NEEDS EVALUATION

The potential Boston Blue line Extension is a two-mile expansion of the line that currently runs from the Logan International Airport to Government Center. The expansion includes two parallel tunnels and an underground station spanning 320 feet at 50 feet in width. The station is directly underneath Newbury Street at the Massachusetts Avenue intersection. The Construction Industries of Massachusetts-Labor Relations Division is asking for a design and construction plan of the potential station tailored to the unique conditions of Newbury Street.

In the design of the Boston Blue Line Expansion, there are several stakeholders and each with individualized needs the factored into the decision-making process. We considered three main groups of stakeholders for this project and ranked them in our perceived order of importance. We ranked surrounding businesses as the primary stakeholders of the extension, because they would be most heavily impacted by the results and process of the project. Then, the next stakeholders considered were the governmental agencies involved in a project of this magnitude. These agencies are legally and financially liable for the project. The final group we included as stakeholders was the general population of Boston. While they still need to be considered, this group might only face minor inconveniences compared to the potential downsides of the other stakeholders.

This project's main constraints are dependent on the stakeholders' needs. The most important of these needs is the mitigation of disruptions and length of the project. Each of our stakeholders benefits from having the shortest construction time with the least amount of disruptions, this is reflected by a large percent weight in decision criteria in Appendix A: Notable Figures and Tables, Table 1. Other constraints include cost, which is not paramount, but must be included since the agencies are responsible for paying. Noise pollution and vibrations during construction must also be addressed, as they provide disruptions to daily life and the residents of the areas. Making sure the needs of each of the stakeholders are being met to the fullest are the main constraints of the theoretical Boston Blue Line Extension Project.

ALTERNATIVES EVALUATION

The alternative memorandum outlined four proposed earth retention systems for the Hynes Convention Center station for the Boston Blue Line extension. These alternatives were evaluated based on cost, disruption, and water retention effectiveness. The options were a concrete diaphragm wall (slurry wall), sheet pile wall, secant wall and a “no change” option.

The concrete diaphragm wall (slurry wall) was chosen as the preferred alternative, because it provides soil stabilization, structural stability, and stakeholders needs despite it having higher upfront costs. Further details on all evaluated alternatives and their evaluations can be referenced in Appendix F: Alternatives Memorandum.

ALTERNATIVE SELECTION

The alternative selection memorandum highlighted the decision-making process for identifying the most suitable earth retention system for the proposed Hynes Convention Center station on the Boston Blue Line extension. Four alternatives were presented: concrete diaphragm wall (slurry wall), sheet pile wall, secant pile wall, and a “no change” alternative. Each alternative was evaluated based on criteria such as construction time and disruption, user accessibility and design, construction cost, maintenance cost, and sustainability refer to Appendix A, Table 1. These criteria were scored on a scale of 0 to 5, with 5 representing the best option.

The scoring results were multiplied by their respective weighted criteria to generate overall scores for each alternative Appendix A, Table 2. The concrete diaphragm wall received the highest score due to its superior structural performance, minimal vibrations, water retention and long-term cost benefits. The sheet pile wall ranked second, offering cost-effective construction, but brings concerns with stability and vibrations. The secant pile wall ranked third, due to its high cost and lack of water retention. The “no change” alternative ranked the lowest, as it failed to meet the project goals.

A sensitivity analysis, Appendix A, Table 3, was conducted to ensure a fair evaluation of all alternatives. Feedback from community partners helped refine the cost estimates and evaluation criteria. For example, the analysis incorporated the additional costs of waterproofing for slurry walls and the removal of obstructions for sheet pile walls. These adjustments confirmed the concrete diaphragm wall as the optimal solution, providing a permanent structural component for the station while minimizing disruption to the surrounding area.

The recommended concrete diaphragm wall meets the structural, economic, and environmental needs of the project while addressing community concerns, such as construction disruptions. A detailed explanation of this selection process can be found in Appendix G: Alternatives Selection Memo. Feedback from our stakeholders was utilized in refining this memorandum.

CONCLUSION AND RECOMMENDATIONS

This project involved designing a new train station for the Boston Blue Line extension from Government Center to Hynes Convention Center. Our goal was to design an earth retention system that ensures soil stability and supports the construction of the new train station. The primary constraints included addressing Boston's unique soil conditions, navigating urban setting challenges, and meeting the needs of key stakeholders, such as commuters, local businesses, and residents.

The main challenge was to design an efficient earth retention system to support the deep excavation required for the station while ensuring long-term structural efficiency. Four alternatives were evaluated: the concrete diaphragm wall (slurry wall), sheet pile wall, secant pile wall, and a "no change" alternative. Each alternative was assessed based on weighted criteria reflecting stakeholder needs and feedback from community partners. Construction time and disruptions were weighted at 35%, user accessibility and design at 30%, construction cost at 20%, and maintenance cost at 15%. The final alternative rankings are detailed in the decision matrix and sensitivity analysis in Appendix A, Tables 2 and 3. Cost calculations for the recommended alternative and the life cycle cost analysis are provided in Appendix D.

Our recommended solution, the concrete diaphragm wall, serves as a permanent structure functioning as both the earth retention system and a foundational component of the station. Design drawings are in Appendix B. This design effectively prevents groundwater seepage and minimizes vibrations during installation, reducing the risk of foundation settling in surrounding buildings. While the initial costs are higher, the concrete diaphragm wall requires minimal maintenance, making it the most economical choice over time. This construction method has demonstrated success in previous Boston projects, such as the Big Dig, where it provided effective stabilization for the area's unique soil conditions.

Sustainability was a key consideration in selecting the earth retention system. Important factors included reusing excavated fill, employing local contractors familiar with Boston's Blue Clay, and minimizing ground settling around the site. While the concrete diaphragm wall has higher upfront costs, its durability, low maintenance requirements, and ability to serve as an additional structural element make it the most sustainable option. Trade-offs involved prioritizing long-term sustainability over initial costs to ensure reduced environmental impact and maintenance needs over time.

In the analysis of the life cycle cost for the concrete diaphragm wall, the main expenses were focused on the engineering, designing and contingencies of the project. The estimated initial cost to construct the slurry wall was $9,833,000, which additionally involved the permits, disposal and external costs. The permits, deposal, and external costs make up about 16% of the total initial cost compared to the engineering, design, and contingencies portion. In calculating the full project cost, the team made sure to project both labor and material costs to account for expenses related to employees and contractors. The projected material and labor cost was about $5,315,000, seen in Appendix D. These permanent structures can have a design use life for 50 years or potentially more with continual maintenance. The annual maintenance cost was estimated at approximately $22,000, with fluctuations depending on the type of maintenance required and the structure's stage in its design life. With that in mind and an interest rate of 6%, the present worth of the slurry wall was calculated at $10,196,760. Now, this cost seems low for the construction and excavation of the structure, but this life cycle analysis only involves the construction and maintenance of the structure and not the materials, heating, and lights that go into the finalization of building a station. All the costs and breakdowns of the calculations of the costs are provided in Appendix D.

The next steps involved in the construction of the slurry wall could potentially be installing inclinometers to surrounding buildings and the soil surrounding the structure. Inclinometers are devices that measure the slope or elevation displacements in the ground. By adding these sensors, it would guarantee that the project is running smoothly while ensuring the community's safety as well. Besides installing sensors, the next steps for this project include providing the preliminary design and construction plans for the Spring capstone group that will continue to work on this project. This is a yearlong project that consists of the design and plan for building an earth retention system as well as sourcing structural elements and materials to build the physical train station and construct a design of the platform space. A final report with the cumulative information will be submitted to this competition and another group of students will complete the project.

REFERENCES

[1] Roma, John. Lambrechts, Jim. (n.d.) “Student Competition in Heavy Civil Infrastructure Design/Construction.” *Construction Industries of Massachusetts – Labor relations Division*. (Aug. 28, 2024).

[2] UCF. (n.d.). “Slurry walls construction methodology.” *Slurry Walls Construction Methodology | Geofoam, Styrofoam, EPS & Polystyrene | Universal Construction Foam*, <https://universalconstructionfoam.com/projects/slurry-walls-construction-methodology/> (Oct. 3, 2024).

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[8] Massachusetts Bay Transportation Authority. (n.d.). “Speed Restrictions.” *MBTA*, mass.gov, <https://www.mbta.com/performance-metrics/speed-restrictions> (Oct. 7, 2024).

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APPENDICES

APPENDIX A: NOTABLE FIGURES AND TABLES

Table 1: Evaluation Criteria for Alternatives

Evaluation Criteria	Criteria Weight (%)
Construction Time and Disruption	35
User Accessibility and Design	30
Construction Cost	20
Maintenance Costs	15
Total	**100**

Table 2: Criteria Matrix Evaluation for Recommended Alternative

Criteria	Weight (%)	Concrete Diaphragm Wall		Sheet Pile Wall		Secant Wall		No Change	
		Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)
Construction Time and Disruption	35	4	28	3	21	4	28	5	35
User Accessibility and Design	30	5	30	3	18	3	18	1	6
Construction Cost	20	3	12	4	16	1	4	1	4
Continued Maintenance Costs	10	4	8	5	10	1	2	1	2
Sustainability	5	4	4	4	4	1	1	1	1
Total	**100**	**82**		**69**		**53**		**48**	

*Rating vales ranked from 0-5 (0=N/A, 5 = Best)

Table 3: Sensitivity Analysis Matrix

Criteria	**Weight (%)**	**Concrete Diaphragm Wall**		**Sheet Pile Wall**		**Secant Wall**		**No Change**	
		Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)
Construction Time and Disruption	35	4	28	4	28	4	28	1	7
User Accessibility and Design	30	5	30	3	18	3	18	1	6
Construction Cost	20	4	16	4	16	2	8	1	4
Continued Maintenance Costs	10	4	8	5	10	1	2	1	2
Sustainability	5	4	4	4	4	1	1	1	1
Total	**100**	**86**		**76**		**57**		**20**	

*Rating vales ranked from 0-5 (0=N/A, 5 = Best)

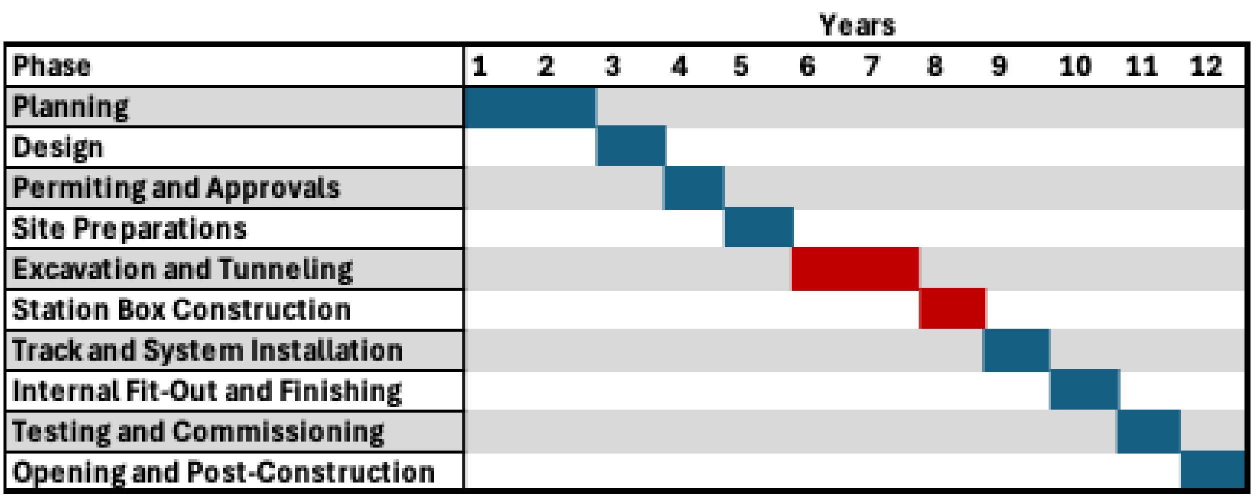


Figure 1: Total Project Timeline

*The areas highlighted in red are the phases of the project that the group had decided to focus on.

APPENDIX B: DESIGN DRAWINGS

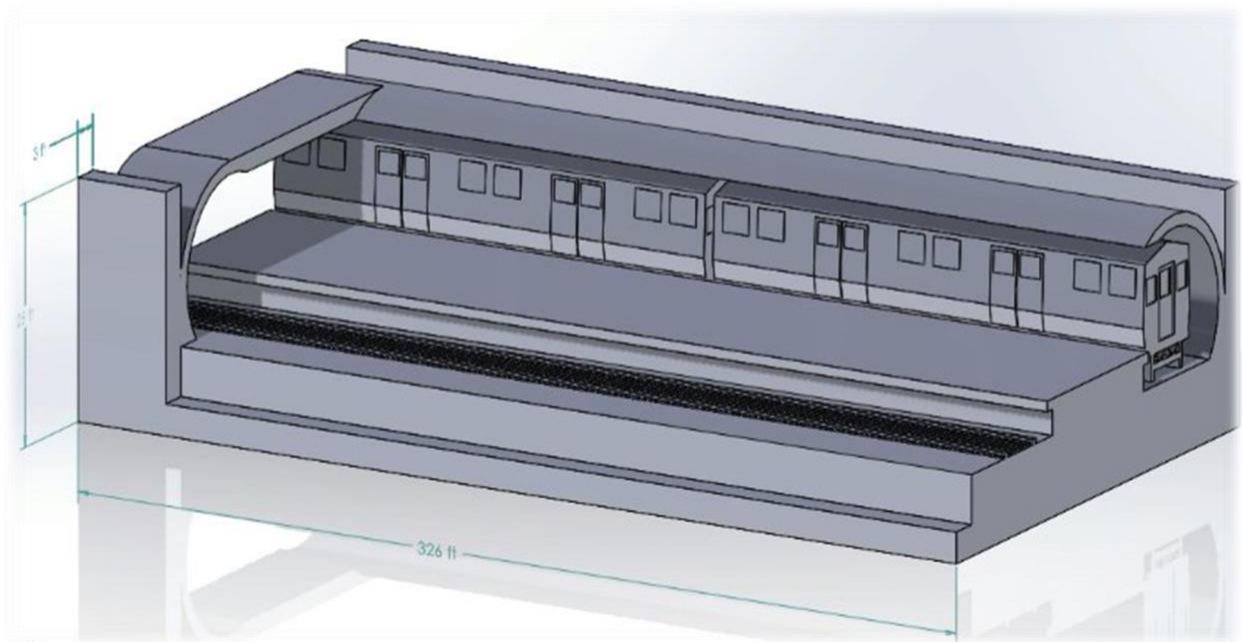


Figure 2: Diagram of train station platform including the dimensions of slurry wall.

Designed:

Checked:

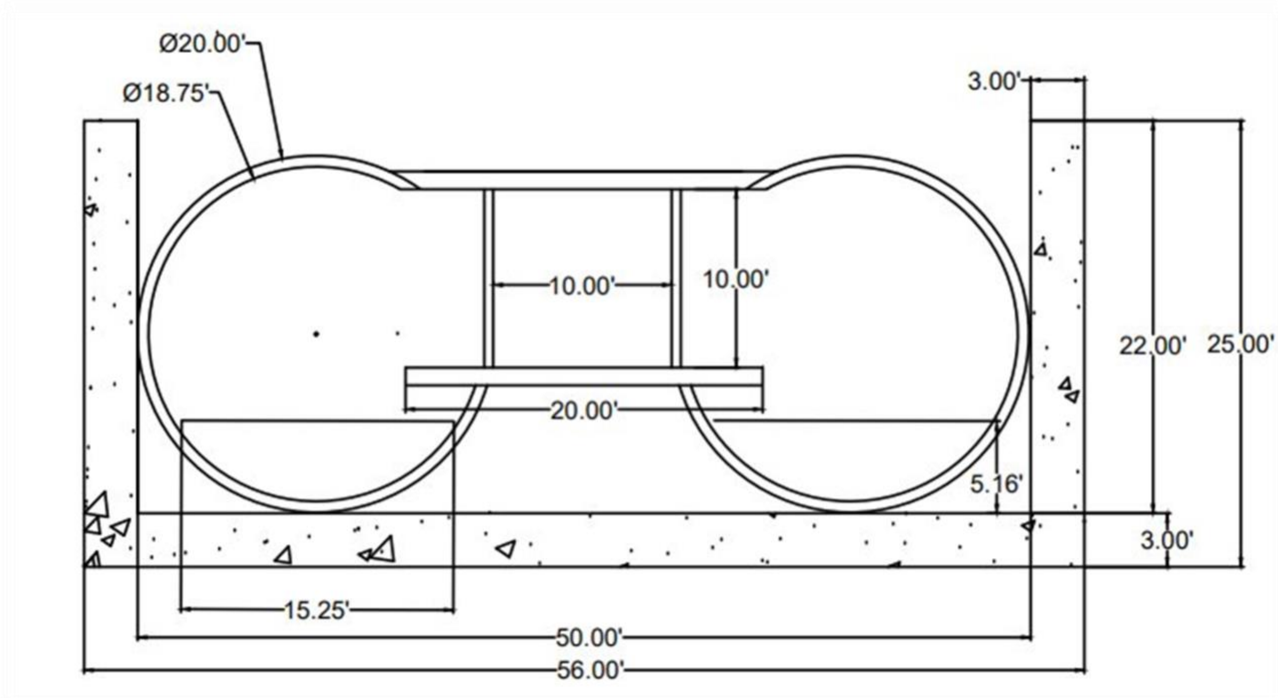


Figure 3: Cross section view of concrete diaphragm wall with two 20’ diameter tunnels.

Designed:

Checked:

Figure 4: Visual Outline of Project Footprint
Source: Google Earth

APPENDIX C: EXCAVATION VOLUME CALCULATIONS

Volume Calculations (For 150-foot length of wall, 320-foot platform)

West to East Walls:

$$2\ walls * (150ft * 53ft * 3ft) = 47{,}700\ ft^3$$

South to North Walls:

$$2\ walls * (56ft * 53ft * 3ft) = \ 17{,}808\ ft^3$$

Volume of Overlap:

-All 4 corners are included in both cubic feet found above, need to account for double inclusion

$$4\ corners * (3ft * 53ft * 3ft) = \ 1{,}908\ ft^3$$

Total Cubic Area of Slurry Needed

$$47{,}700\ ft^3 + 17808\ ft^3 - 1908\ ft^3 = 636{,}000\ ft^3$$

Convert from ft^3 to yd^3

$$636{,}000 ft^3 * \frac{1\ yd^3}{27\ ft^3} = 2355.56\ yd^3$$

Total Fill Removed

$$326\ ft * 56\ ft * 53\ ft = 967{,}568\ ft^{\ 3}$$

Convert from ft^3 to yd^3

$$967{,}568 ft^3 * \frac{1\ yd^3}{27\ ft^3} = 35{,}836\ yd^3$$

Calculated:

Checked:

Volume Calculation (For 326-foot exterior length, 320-foot platform)

West to East Walls:

$$2\ walls * (326ft * 53ft * 3ft) = 103{,}668\ ft^3$$

South to North Walls:

$$2\ walls * (56ft * 53ft * 3ft) = \ 17{,}808\ ft^3$$

Volume of Overlap:

-All 4 corners are included in both cubic feet found above, need to account for double inclusion

$$4\ corners * (3ft * 53ft * 3ft) = \ 1{,}908\ ft^3$$

Total Volume of Slurry Needed

$$47{,}700\ ft^3 + 17808\ ft^3 - 1908\ ft^3 = 119{,}658\ ft^3$$

Convert from ft^3 to yd^3

$$119{,}658 ft^3 * \frac{1\ yd^3}{27\ ft^3} = 4428.44\ yd^3$$

Calculated:

Checked:

APPENDIX D: COST CALCULATIONS

*Material and Labor Cost of $1200/yd^3$ taken from feedback from community partner from Feedback from Will Spielvogel on Alternatives Memo (Received 10/14/2024) located in *Appendix J*

Cost Calculations (For 150-foot length of wall, 320-foot platform)

Material and Labor Cost = $1200/yd^3$

$$2355.56\ yd^3 * \frac{\$1,200}{1\ yd^3} = \$2,826,666.67$$

Final Material and Labor Cost = **$2,827,000**

Cost Calculations (For 326-foot exterior length, 320-foot platform)

Material and Labor Cost = **$1200/yd^3$**

$$4428.44\ yd^3 * \frac{\$1,200}{1\ yd^3} = \$5,314,133.33$$

Final Material and Labor Cost = **$5,315,000**

Calculated:

Checked:

Total Cost Analysis (150-foot length)

Table 4: Cost Breakdown for a Concrete Diaphragm Wall with a length of 150-feet.

Description	Percent of TMLC (%) *	Cost
Engineering	25	$706,750.00
Design	15	$424,050.00
Permits/Approvals	10	$282,700.00
Contingencies	15	$424,050.00
Disposal	10	$282,700.00
Externalized Costs	10	$282,700.00
Total		$5,230,000.00

Total Cost Analysis (326-foot length)

Table 5: Cost Breakdown for a Concrete Diaphragm Wall with a length of 326-feet.

Description	Percent of TMLC (%) *	Cost
Engineering	25	$1,328,750.00
Design	15	$797,250.00
Permits/Approvals	10	$531,500.00
Contingencies	15	$797,250.00
Disposal	10	$531,500.00
Externalized Costs	10	$531,500.00
Total		$9,833,000.00

*The percentages values for the cost breakdown were evaluated on the upper end of the range of values provided in the assignment breakdown because of the complexity of the project. Both options were calculated as to provide options for the Capstone Design Spring 2025 group that will continue this project.

Calculated:

Checked:

Life Cycle Cost Analysis for Selection (Concrete Diaphragm Wall)

Useful Life (n) = *50 years*

Annual Maintenance Costs (A) = *$22,000*

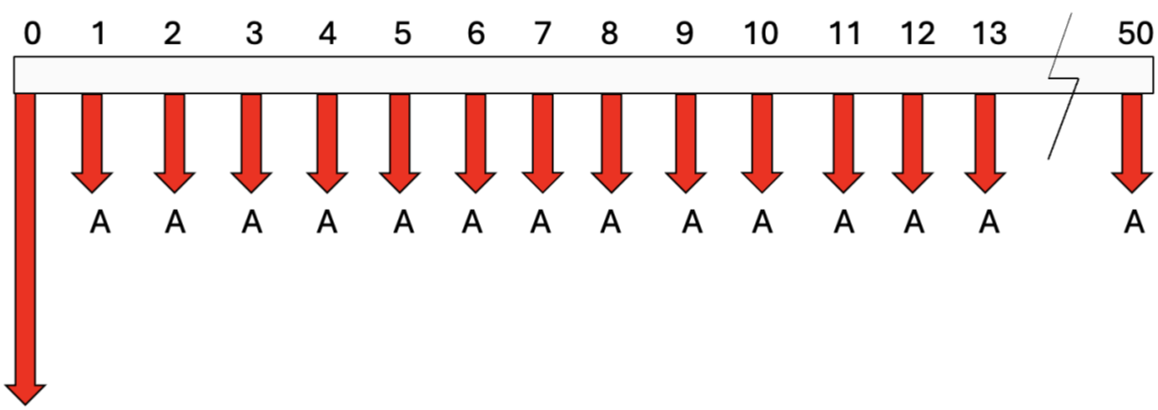
Assumed interest Rate (*i*) = *%6.00*

Calculations:

$$Present\ Worth = Initial\ Cost\ +\ A\ *\ \frac{((1+i)^n - 1)}{(i * (1+i)^n)}$$

$$Present\ Worth = \$9{,}850{,}000\ +\ \$22{,}000\ *\ \frac{((1+.06)^{50} - 1)}{(.06 * (1+.06)^{50})}$$

$$Present\ Worth = \$10{,}196{,}760\ (round\ up\ to\ \$10{,}200{,}000)$$



Initial Cost (I.C.) = **$9,850,000**
Annual Maintenance Cost (A) = **$22,000**
Estimate Design Use Life = **50 years**
Present Worth= **$10,196,760 (rounded up to $10,200,000)**

Calculated:

Checked:

APPENDIX E: SCOPING AND NEEDS MEMORANDUM

Memorandum

To: Construction Industries of Massachusetts-Labor Relations Division
From: Stites Allen, Joey Collentro, Megan Messina, Annie O'Hara
Date: September 18th, 2024
Subject: Boston Blue Line – Project Needs Memorandum and Scoping Agreement

Introduction

Our UVM Capstone group was tasked by the Construction Industries of Massachusetts-Labor Relations Division client to design a station for the Hynes Convention Center stop, along with a construction plan for the station for the Boston Blue Line, addressing the need for an extension of the Blue Line, which runs beneath Hynes Station. This project should include station layout arrangements, as well as specifications for structural member types, sizes, and materials required for constructing the station. We are tasked to design an earth retention system that will aid in construction of the new Hynes Convention Center train station.

There are various constraints that need to be considered during the station's construction, with details provided on the station's dimensions and elevations to assist with the planning process. A key consideration for this project is whether to drill a double or single tunnel for the station, as this decision will significantly impact the construction schedule and overall project cost. The final design will be part of a competition presented at the end of the school year before a panel of five judges.

Background Information

Provided background information includes:

- Map of exiting trains, including the Green Line Train.
- Map of proposed Blue Line extension.
- Bedrock contours
- Boring Logs
- Cross section of current soil condition and tunnel under Newbury Street.
- Dimensioned cross section drawings for single and double train tunnels.

Stakeholders and Their Needs

Table 6: Stakeholder Ranking

Stakeholder Rank	Stakeholder	Stakeholder Needs
Primary	Businesses*	The businesses along the construction route are the primary concern because of the potential closures and/or lack of accessibility they will endure.
Secondary	Governmental agencies - City of Boston - Boston Water & Sewer Commission - Eversource: Residential Energy Provider	They need to ensure that the project is financially, environmentally, and socially responsible, while making sure it is helpful to the citizens.
Tertiary	Citizens of Boston	The needs of the citizens are to have as little disruptions to their daily lives as possible during the construction process.

*Refer to Table 5 for detailed list of business that will be affected by construction.

Table 7: List of Businesses Along Newbury Street.

Business	Address
Boston Club Sports	361 Newbury Street
Urban Outfitters	361 Newbury Street
TJ Maxx	360 Newbury Street
Muji	359 Newbury Street
Johnson Paint	355 Newbury Street
Lf Boston	353 Newbury Street
Arc'teryx	352 Newbury Street
Motion Stretch Studio	351 Newbury Street
GNC	351 Newbury Street
Brandy Melville	351 Newbury Street
Starbucks	350 Newbury Street
Pure Barre	348 Newbury Street
Back Bay Boxing	348 Newbury Street
Patagonia	346 Newbury Street
Roots	344 Newbury Street
Forever 21	343 Newbury Street
Reformation	342 Newbury Street
SLT	341 Newbury Street
Uniqlo	341 Newbury Street
Diesel	339 Newbury Street
Title Boxing	338 Newbury Street
Trident Booksellers	338 Newbury Street
Lululemon	337 Newbury Street
Town's Nails & Skin	336 Newbury Street
Boston Smoke Shop	336 Newbury Street
Newbury Comics	336 Newbury Street
Xtend Barre	336 Newbury Street
Sunglass Hut	335 Newbury Street
Champion	333 Newbury Street
Salon Persona	331 Newbury Street
Bauer Wines	330 Newbury Street
Bedgear	330 Newbury Street
Madewell	329 Newbury Street
Vans	328 Newbury Street
Sonsie	327 Newbury Street
The North Face	326 Newbury Street
City Smoke Shop	324 Newbury Street
Which Wich	324 Newbury Street
Boston Architectural College	320 Newbury Street

Constraints

Current constraints include budget, construction scheduling, Boston's geography, and its urban setting. Our goal is to propose three design options for earth retention systems for the train station construction, prioritizing water retention, structural stability, and minimal construction disruptions. Boston's urban environment presents challenges, daytime construction may be inefficient, while nighttime work could disrupt residents, increase labor costs, and require additional permits. Boston's unique geological soil, characterized by Boston Blue Clay, will require further geotechnical research to determine the best earth retention system.

Summary and Goals

The goal is to develop a safe, cost-effective construction plan and schedule for the extension of Boston's Blue Line. This comprehensive plan will include a well-defined timeline and detailed financial breakdown, ensuring minimal disruption to the daily lives of Bostonians. By carefully addressing the needs of all stakeholders, we aim to achieve the project objectives efficiently while balancing the interests of the community and the city's infrastructure. This has been compiled into the accompanying scoping agreement letter.

Research will be conducted to create a design and construction plan for this project, focusing on the necessary materials and identifying where the platform construction will begin. From there, we will approach three different potential designs for the construction portion of the project and corresponding station.

The expected deliverables include detailed structural modeling, a comprehensive cost estimate for the project and construction phases, and a preliminary construction schedule. These components will provide a clear understanding of the project's scope, timeline, and financial requirements.

APPENDIX F: ALTERNATIVES MEMORANDUM

Memorandum

To: Construction Industries of Massachusetts-Labor Relations Division
From: Stites Allen, Joey Collentro, Megan Messina, Annie O'Hara
, , , &
Date: October 8, 2024 (Updated October 14, 2024)
Subject: Boston Blue Line Extension – Project Alternatives Memorandum

Introduction

We were asked to design a train station for the Boston Blue Line extension from Government Center to Hynes Convention Center, as shown in **Figure 5.** Our task is to create a rapid construction plan for a new station that would provide significant benefits to Boston's transit system and its residents.

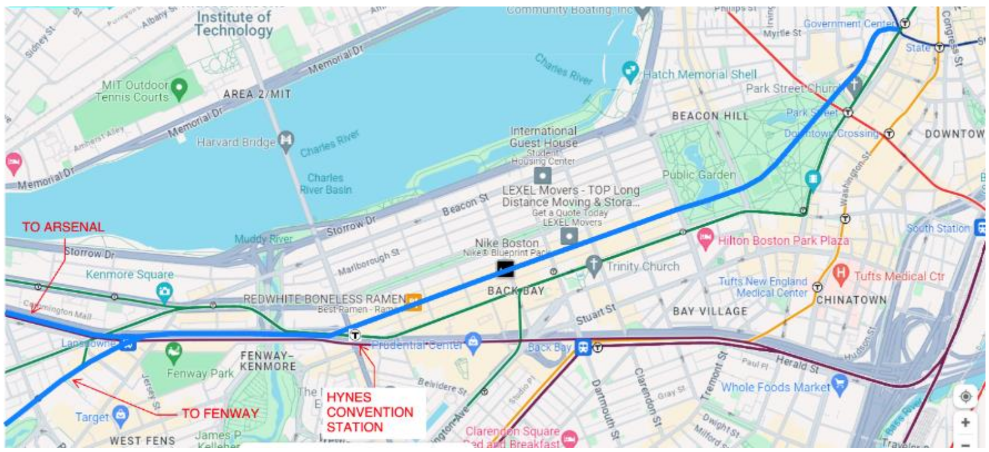


Figure 5: An overview of the potential expansion of the Blue Line.
Source: Google Maps

This memo presents our recommended alternative solutions for an earth retention system during the construction of a new Blue Line station. Each alternative addresses the project's key constraints and stakeholder needs, including cost, construction time, and impacts on daily life. Our goal is to design a permanent station that increases convenience for local transit while minimizing disruption.

BACKGROUND INFORMATION

Our team was provided with a map of the existing train lines, bedrock contours, and cross-section of current soil conditions beneath Newbury Street [1]. The competition requires us to develop a design and construction plan for this project, with a focus on the necessary materials and construction practices for the platform. The platform's construction will require top-down excavation and must be designed to withstand the soil conditions of the Back Bay area, as well as the surrounding buildings and infrastructure.

KEY CONSIDERATIONS

Evaluation Criteria:

Several factors must be considered in evaluating the alternatives. Being conscientious of all our stakeholders and their needs allows us to develop the best alternatives. One of the primary considerations is the cost of each alternative. While cost may not be the final decision maker, it could rule out certain construction options. Soil stability is also critical, as Boston's soft soil conditions make stability and groundwater management important. Another important factor is the impact on residential life, including disruptions to daily life and commuting. This includes factors like length of construction and potential noise or vibrations. Knowing how each alternative could potentially create disruptions in daily life is an important aspect of the planning process. Notably, three of the alternatives require complete excavation, which would result in significant disruptions for Bostonians and potential delays in existing car and train traffic.

Stakeholders/Needs:

The primary stakeholders for this project include local businesses, particularly those along Newbury Street, as shown in ***Appendix E, Table 5***. This area is expected to be used for staging and will also be the site for the station's construction. Other stakeholders impacted by the Hynes Convention Center station extension include nearby residents, tourists visiting Boston, and commuters who regularly use the Green or Blue Lines. During excavation, roadways will be blocked, and noise will be generated near the construction site. As illustrated in **Figure 9**, the street is typically very busy during the day, so most of the construction is planned for nighttime, which will heavily affect nearby apartments and residents. Additionally, the existing infrastructure supporting the Green Line at Hynes Station will need to be reassessed, and construction may lead to slower train operations, delays, or the need for bus connections, causing disruptions for MBTA commuters and travelers.

PROJECT ALTERNATIVES:

ALTERNATIVE 1: CONCRETE DIAPHRAGM WALL

Estimated Cost: *$45 per square foot*

A concrete diaphragm wall (also known as a slurry wall) is a technique used to build reinforced concrete walls that stabilize soft soils and efficiently prevent ground water flow during and after construction. These walls are typically around 3 feet thick and can be either permanent or temporary. For the construction of Hynes Station, the wall will be permanent and serve as a structural component for the station as well as any temporary structures to be placed over the station during construction. It is not recommended that the typical bentonite slurry be used in salt water prone environments, so this wall would be constructed using either attapulgite clay or synthetic polymers.

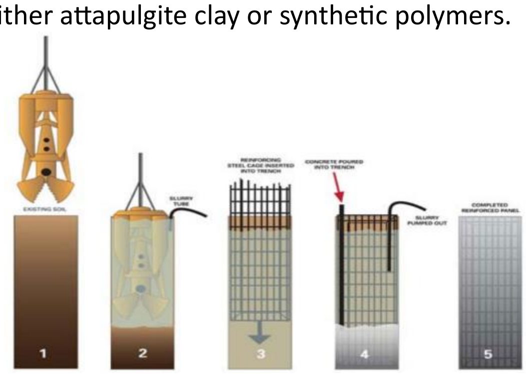


Figure 6: Example of the installation of slurry walls.
Source: https://foundationequipment.wordpress.com/wp-content/uploads/2012/08/capturada.jpg

Construction

Construction begins with the installation of concrete guide walls to guide the trench cutter and support the upper part of the wall. Stop pipes are installed as guides for excavation. The excavation of the trench is performed using either a mechanical or hydraulic clamshell [2]. Slurry, a mixture of water and bentonite, is pumped into the excavated trench as the clamshell continues digging through the slurry. Once the desired depth is reached, metal reinforcements are added to the trench. Finally, permanent concrete is poured into the trench using tremie pipes. Due to the density difference between the concrete and the slurry, the concrete displaces the slurry. The displaced slurry is then pumped out and can be reused. Afterward, the stop pipes are removed, and the next alternating panel is excavated.

Strengths

- Foundation for Temporary Decking
- Permanent Wall
- Significantly Reduced Vibrations
- Minimize Groundwater Seepage

Limitations

- Cost
- Potential for Panel Collapse
- Staging for Equipment
- Slower Installation Time
- Potential Need for Pre-stabilization of Soil

ALTERNATIVE 2: SHEET PILE WALL

Estimated Cost: $35 per square foot

Sheet piles are a highly effective earth and liquid retention system, composed of large interlocking steel sheets that create a continuous, sturdy wall, offering reliable lateral support in both temporary and permanent applications. Known for its efficiency, sheet piling is one of the most widely used earth retention techniques, particularly in projects where dewatering of the ground is not feasible or practical. Beyond its structural benefits, sheet piling also supports sustainability efforts by using recycled steel, reducing material waste, and promoting environmental responsibility. Its versatility, strength, and eco-friendly attributes make sheet piles a preferred choice for complex excavation projects and long-term earth retention solutions [3].

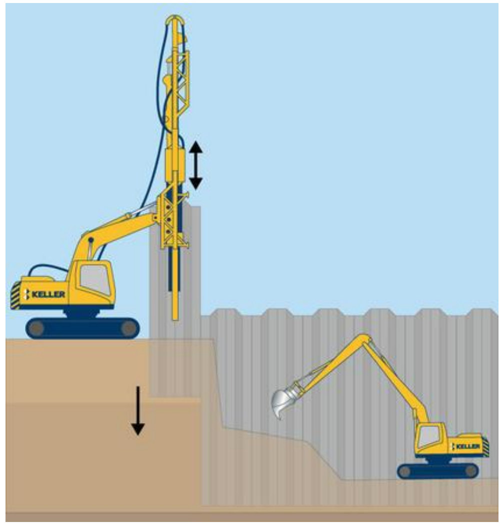


Figure 7: Installation of Sheet Pile walls.
Source: https://www.keller-na.com/expertise/techniques/sheet-piles

Construction

Sheet pile walls are typically constructed by first digging a pre-trench, which allows for the removal of any deep obstructions that could interfere with the wall's installation. Once the site is cleared, precast sheet piles are vibrated into the ground from the surface down to the clay layer. If the wall needs to extend beyond the clay, a diesel impact hammer is used to drive the piles deeper through the clay. Since sheet pile walls cannot directly support the structure, the enclosure must be large enough to accommodate the actual construction inside. After the wall is in place, additional work is required to ensure the stability and waterproofing of the structure, particularly in projects like underground stations.

Strengths

- Most Cost Effective
- Waterproofing
- Minimal Construction Footprint
- Uses Precast Sheets

Limitations

- Removal of Deep Obstructions
- Larger Footprint of Station Box
- Greater Lateral Deflection
- Noise from Construction
- Possible External Damage to Surrounding Structures

ALTERNATIVE 3: SECANT PILE WALL

Estimated Cost: $400 per square foot.

Secant Piles walls are alternating columns of standard concrete and reinforced concrete to create a sealing wall before excavation of the station. The columns overlap with each other by approximately 10% of their diameter to form a permanent continuous structure in the ground. Secant walls provide segmented construction with lower construction vibrations and disruptions. The cost of the secant pile walls can be up to $32,000 per cubic foot, which makes it an expensive option per unit length. Secant walls have a degree of water retention but cannot be trusted as a permanent watertight structure and further waterproofing would be necessary.

Figure 8: Installation and construction of a secant pile wall.
Source: https://brextor.com/en/advisor/pile-wall/

Construction

Construction of secant walls requires heavy machinery and street access for drilling and backfilling. Total road closures would likely be necessary but only required during active drilling and back fillings. The drilling of each row of columns can be segmented to mitigate road closures to times of less inconvenience.

Strengths

- Effective in a wide variety of soil conditions.
- Little deformation and settlement.
- Can carry high loads from surrounding structures.
- Less vibration during construction.

Limitations

- Not watertight
- Difficulty with quality control and inspection.
- Higher cost associated with technology.

ALTERNATIVE 4: REMEDIATE THE GREEN/BLUE LINES

Estimated Cost: Yearly Upkeep + Maintenance.

Proposed as a fourth alternative is to not extend the Blue Line, which will still end at Government Station and not continue to connect to the existing Green Line at Hynes Station. Due to this project being a competition, this alternative is not within the project's scope. The current conditions of the Blue Line will stay the same as well as the conditions of the Green Line.

There will be no extensive construction of the Blue Line or construction of a new station because this alternative does not follow the competition guidelines. But there are some proposals that could improve the existing Blue and Green Lines [6]. The proposed improvements include investing more in the bus and subway systems to enhance speed and reliability, and continued maintenance on both the bus and subway lines [7].

Figure 9: Existing above ground conditions of Hynes Station.
Source: Google Earth.

Construction

Although no major construction is currently underway, the planned improvements focus on enhancing travel times, increasing safety, and improving the reliability of transit services. These improvements include eliminating speed restrictions, repairing tracks, and providing more consistent service notifications. Speed restrictions are areas where trains are required to slow down due to safety concerns. By repairing the rails and removing these restrictions, the transit service can improve overall efficiency and ridership. As of October 7, 2024, the Green Line has two active speed restrictions. Addressing these slowdowns, along with those on other lines, could significantly boost the system's performance and passenger experience [8].

Strengths

- Does not cause disturbance to Bostonians everyday life.
- No major construction will be conducted.
- Cheapest option

Limitations

- Does not add an additional stop at Hynes Convention Center.
- Does not meet the requirements of the competition.
- Does expand the MBTA.

SUMMARY AND CONCLUSIONS:

After evaluating the current proposed alternatives, we can rank these alternatives based off the project's needs and the feasibility of construction. Currently, it is assumed that the permanent slurry wall will be most likely to meet the community's needs due to its stability, groundwater management, and performance in unstable soil conditions. The tie-back sheet pile wall is assumed to be the second choice due to its prefabrication and groundwater management, but a major drawback is the vibrations that occur during installation. These vibrations could face backlash from the community because of the disruption to the surrounding area and the public perception of a constant vibration. The secant pile wall could be ranked third, due to its high permeability. The remediation alternative is the least preferred, as it does not fulfill the project's objectives. Our final recommendation will be made after gathering input from our community partner and conducting further research on the alternatives, using a multi-criteria decision-making process. The criteria we plan to use is presented in ***Table 6.***

Table 8: Initial Evaluation Criteria

Evaluation Criteria	**Criteria Weight (%)**
Construction Time and Disruption	35
User Accessibility and Design	30
Construction Cost	20
Maintenance Costs	15
Total	**100**

We will ask our community partner for feedback on these criteria and their proposed weightings on each alternative, and we will discuss the alternatives further during our interim design review. Based on this input, we will provide a final recommended design alternative that best aligns with both the project's goals and stakeholder needs.

APPENDIX G: ALTERNATIVES SELECTION MEMORANDUM

Memorandum

To: Construction Industries of Massachusetts - Labor Relations Division
From: Stites Allen, Joey Collentro, Megan Messina, Annie O'Hara
Date: November 1, 2024
Subject: Boston Blue Line Extension – Project Alternatives Selection Memorandum

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INTRODUCTION

We were tasked with designing a train station for the Boston Blue Line extension from Government Center to Hynes Convention Center. Our objective was to create a rapid construction plan for a new station that would provide significant benefits to Boston's transit system and its residents. This memorandum explains and analyzes our decision regarding the construction method for the deep excavation and earth retention system used in the station's design. Based on our analysis, we recommend a concrete diaphragm wall (commonly known as a slurry wall) for earth retention and station construction. This alternative best meets the requirements evaluated in **Table 7**.

BACKGROUND INFORMATION:

Preliminary considerations were evaluated for this project including scoping letter, project needs memo, and alternatives memo. With feedback from our community partners William Spielvogel, Construction Senior Advisor, and Ken Pidgeon, P.E. in **Appendix J,** we addressed new limitations and re-evaluated costs to finalize the best alternative. During the design presentation, our community partners recommended further investigation into the costs and waterproofing of the slurry walls. As a result, we recalculated the slurry wall costs using updated estimates and correct units. For the steel sheet pile walls, feedback suggested incorporating the removal of obstructions for deep excavation into our cost estimates and planning for permanent bracing of the retention system. These considerations primarily impact the cost of the sheet pile walls but also add time for obstacle removal and for constructing a retention structure with permanent bracing like a slurry wall. With our community partners' feedback in mind, we can now make a final decision on the best alternative moving forward.

ALTERNATIVES EVALUTAION:

Alternatives Considered:

Each of the four alternatives considered is described in our previous Alternatives Memorandum in **Appendix F,** along with their respective costs per square foot. Alternative 1 is a permanent slurry wall with reinforced concrete walls that remain in place after construction, serving as a structural component of the station. Alternative 2 is a sheet pile wall that interlocks steel sheets to provide greater lateral support, suitable for deep excavation. Alternative 3 is a secant pile wall that utilizes standard concrete and reinforced concrete columns that overlap to create a continuous wall. Lastly, Alternative 4 is a "do-nothing" option, which does not extend the Blue Line but focuses instead on the maintenance of the current Blue and Green Lines.

Evaluation Criteria:

Table 9: Final Evaluation Criteria

Evaluation Criteria	**Criteria Weight (%)**
Construction Time and Disruption	35
User Accessibility and Design	30
Construction Cost	20
Maintenance Costs	10
Sustainability	5
Total	**100**

Construction Time and Disruption

Construction time and disruption measures the duration of the earth retention wall construction as well as its impact on nearby businesses and residents. Each alternative is rated on a scale from 0 to 5, with 0 indicating "not applicable" or the lowest score, and 5 representing the most favorable option. The slurry wall received a rating of 4, as it creates minimal vibrations that could otherwise affect soil strength and the wooden foundations of surrounding buildings. The slurry wall can also be used as staging for the station itself. Although a sheet pile wall could also serve as an alternative, concerns about stability and excessive vibrations associated with pile driving could negatively impact existing conditions.

User Accessibility and Design

User accessibility and design considerations focus on the ease of constructing the train station box and the contractor's familiarity with slurry wall construction. Each alternative is assessed on a scale from 0 to 5, where 0 indicates "not applicable" or the lowest score, and 5 represents the most favorable option. The slurry wall option received a rating of 5, thanks to its widespread use in previous Boston projects, such as the Big Dig. Local contractors are well-acquainted with this construction technique and have extensive knowledge of the soil conditions in the Back Bay, further enhancing its viability for this project.

Construction Costs

The cost of each alternative is detailed in the Alternatives Memorandum (Updated) found in **Appendix F**. Each option is rated on a scale from 0 to 5, where 0 signifies "not applicable" or the lowest score, and 5 represents the most favorable option. A comprehensive cost breakdown of two potential wall designs is provided in **Appendices C and D**, **Tables 4 and 5.** These breakdowns include the percentage of the total materials and labor cost (TMLC) for each alternative, offering a clear comparison of the financial implications associated with each design.

Maintenance Costs

Maintenance costs reflect the time and investment needed to maintain both the structural integrity and aesthetics of the wall. A life cycle maintenance cost analysis of the diaphragm wall is provided in **Appendix D.** Each alternative is evaluated on a scale from 0 to 5, where 0 means "not applicable" or the lowest score, and 5 represents the most favorable option. This criterion assesses potential post-construction risks, such as flaws in structural integrity and the costs associated with necessary repairs. Additionally, it includes expenses related to waterproofing the wall and ongoing maintenance required to ensure its longevity and appearance over time.

Sustainability

Sustainability considerations include the efficient reuse of fill material, minimized vibrations during construction, support for local contractors, and the long-term structural efficiency provided by the slurry wall. Each alternative is ranked on a scale from 0 to 5, with 0 representing "not applicable" or the lowest score and 5 representing the most favorable option. The slurry wall received a rating of 4 for its reduced environmental impact due to minimal vibration, its contribution to the local economy using familiar, regional contractors, and its proven durability in similar projects, providing a resilient, long-term solution with lower maintenance requirements.

Final Evaluation

Table 10: Final Criteria Matrix for Recommended Alternative.

Criteria	**Weight (%)**	**Concrete Diaphragm Wall**		**Sheet Pile Wall**		**Secant Wall**		**No Change**	
		Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)
Construction Time and Disruption	35	4	28	3	21	4	28	5	35
User Accessibility and Design	30	5	30	3	18	3	18	1	6
Construction Cost	20	3	12	4	16	1	4	1	4
Continued Maintenance Costs	10	4	8	5	10	1	2	1	2
Sustainability	5	4	4	4	4	1	1	1	1
Total	**100**	**82**		**69**		**53**		**48**	

*Rating vales ranked from 0-5 (0=N/A, 5 = Best)

Sensitivity Analysis

A sensitivity analysis was conducted on the alternatives, using different scenarios to evaluate each option from multiple perspectives. The criteria outlined in **Table 7** were applied, leading to two distinct outcomes presented in **Tables 9 and 10**. The first iteration of the matrix takes a more optimistic approach to cost estimates for each alternative. Initial costs provided by our community partner varied in units, so the team adjusted and cross-referenced these values with additional sources. This first iteration also assumes a worst-case scenario for the "No Change" option, projecting that delays in construction would lead to increasing disruptions for the public over time. The second iteration in **Table 10** reconsiders this assumption, instead treating the “No Change” option as having the lowest immediate disruption, as evaluating its long-term impact is beyond the project's current scope. This scenario positions "No Change" as favorable in terms of public impact, specifically by that criterion. Consistent with our team’s initial thoughts, the sheet pile wall emerges as the preferred option in the second iteration; however, this is still subject to further research and input from community partners. Both versions of the sensitivity analysis, alongside feedback from community stakeholders, informed the final criteria matrix in **Table 8**.

Table 11: Sensitivity Analysis Matrix 1

Criteria	**Weight (%)**	**Concrete Diaphragm Wall**		**Sheet Pile Wall**		**Secant Wall**		**No Change**	
		Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)
Construction Time and Disruption	35	4	28	4	28	4	28	1	7
User Accessibility and Design	30	5	30	3	18	3	18	1	6
Construction Cost	20	4	16	4	16	2	8	1	4
Continued Maintenance Costs	10	4	8	5	10	1	2	1	2
Sustainability	5	4	4	4	4	1	1	1	1
Total	**100**	**86**		**76**		**57**		**20**	

*Rating vales ranked from 0-5 (0=N/A, 5 = Best)

Table 12: Sensitivity Analysis Matrix 2

Criteria	Weight (%)	Concrete Diaphragm Wall		Sheet Pile Wall		Secant Wall		No Change	
		Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)	Rating	Weighted Score (%)
Construction Time and Disruption	35	4	28	4	28	4	28	5	35
User Accessibility and Design	30	3	18	3	18	3	18	1	6
Construction Cost	20	3	12	4	16	1	4	1	4
Continued Maintenance Costs	10	3	6	5	10	1	2	1	2
Sustainability	5	4	4	4	4	1	1	1	1
Total	**100**	**68**		**76**		**53**		**48**	

*Rating vales ranked from 0-5 (0=N/A, 5 = Best)

Evaluation Limitations

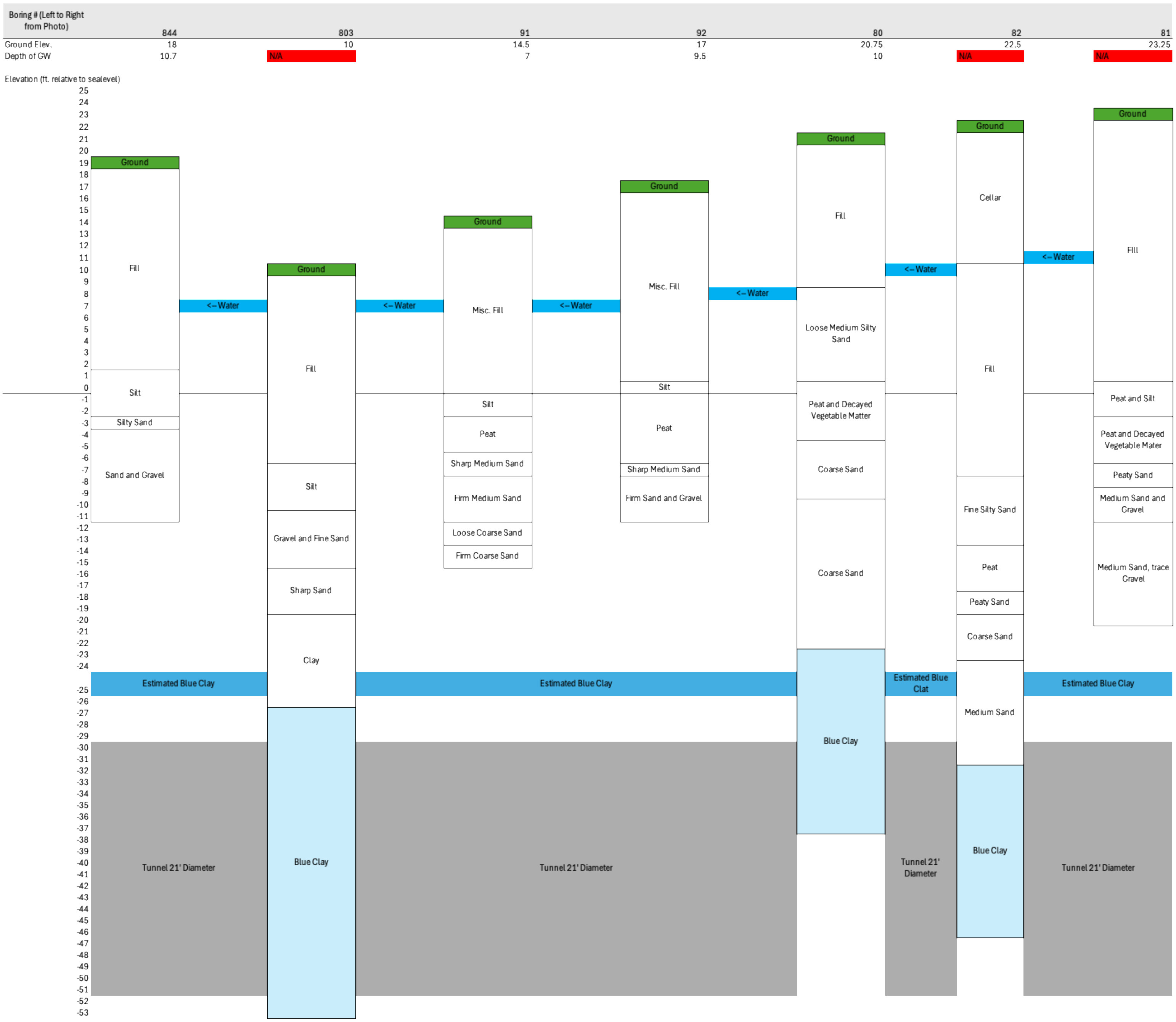
The project limitations were primarily outlined in the project packet from the Construction Industries of Massachusetts-Labor Relations Division (CIM-LRD), as referenced in **Appendix F**. One major constraint was the directive to excavate a 320-foot length for station construction, which could lead to significant backfilling and material waste upon completion. To address this, the team designed and cost-estimated a shorter, 150-foot wall to reduce backfill and material waste. Additionally, we had to factor in that the Tunnel Boring Machine (TBM) had already excavated the extension tunnel, influencing our cost estimates and choice of alternatives to ensure compatibility. Finally, while the project includes the design and construction costs for the station platform, our team was instructed to focus solely on excavation and retention wall alternatives, which limited the materials and costs we needed to evaluate for that portion of the project.

RECOMMENDED ALTERNATIVE:

As stated in our Alternatives Memo, we evaluated our options based on construction feasibility, structural performance, and cost. Each of these criteria was applied to our four potential alternatives using a weighted rating system, displayed in an analysis matrix that informed our final decision to recommend the Concrete Diaphragm Wall as the preferred alternative.

We chose to advance with the Concrete Diaphragm Wall, or Slurry Wall, design due to its expected performance. The Slurry Wall offers superior groundwater retention and maximum security for surrounding structures. Construction considerations were also critical, as slurry walls minimize disruptive vibrations and have a significantly lower risk of delays, especially given the depth required for this project. Although slurry walls may have a higher initial cost, they serve as permanent structures within the station, making them more cost-effective over time. The Slurry Wall provides the best combination of construction feasibility and structural performance at a comparable price to other alternatives.

APPENDIX H: BORING LOGS



Source: Roma, John. Lambrechts, Jim. (n.d.) "Student Competition in Heavy Civil Infrastructure Design/Construction." Construction Industries of Massachusetts – Labor relations Division. (Aug. 28, 2024).

APPENDIX I: PROJECT OUTLINE

1. Project Overview

- Description of the Hynes Station design competition for the CIM-LRD.
- Location: Proposed Blue Line tunnel from Government Center station to Hynes Station and beyond.
- Constraints: Dense urban environment beneath Newbury Street and Massachusetts Avenue, with nearby existing structures and limited available public land.

2. Design Requirements

- **Station Location and Alignment**
    - Station to be beneath Newbury Street, east or west of existing Hynes Station.
    - Consideration of single bore (28 ft. diameter) or twin bore (20 ft. diameter) tunnel options.
- **Platform Configuration**
    - Minimum width: 20 ft. wide center platform.
    - Platform length: 320 ft. to accommodate 6 Blue Line cars (each 48.5 ft. long) with an additional 29 ft. for stopping buffer.
- **Vertical Circulation Elements**
    - Placement of escalators, stairs, and elevators at ends of platforms to maximize platform width.
    - Emergency egress with elevator access at the opposite end of the mezzanine.
- **Mezzanine and Entrance Design**
    - Mezzanine floor approximately 10-15 ft. below street level.
    - Fare collection and card sales area in mezzanine.
    - Entrances from Massachusetts Avenue and existing Hynes Station.
- **Excavation and Construction Constraints**
    - Excavation support walls and consideration of minimal available public land.
    - Possibility to install support walls before TBM tunnel driving.
    - Material handling through newly constructed Blue Line tunnels.
- **Urban Context Considerations**
    - Mitigation of traffic disruption by decking streets shortly after excavation.
    - Planning for delivery and staging of construction materials (steel, concrete, etc.).

3. Structural and Civil Engineering Requirements

- **Tunnel Design**
    - Segmental tunnel linings and innovative solutions for tunnel construction.
    - Minimum tunnel separation, possible reduction from initial 10 ft. distance.
- **Station Structural Elements**
    - Type, size, and material of structural members.
    - Arrangement and support for vertical and horizontal loads.

- **Connection to Existing Infrastructure**
    - Integration with existing Green Line tunnel, which requires major overhaul.
    - Design for connection points and transitions.

4. Design Constraints and Challenges

- Congested urban setting.
- Proximity to existing structures (Back Bay row houses).
- Soil conditions (Boston Blue Clay, organic silt, etc.).
- Potential disruptions (Massachusetts Avenue intersection, Green Line tunnel).

5. Deliverables

- **Design Submittal**: 15%-20% design level including:
    - **Station Layout and Arrangement**
        - Schematic design showing station space arrangements, circulation, and platform configurations.
    - **Structural Details**
        - Preliminary details of civil structures (platforms, walls, supports).
        - Types, sizes, and materials of structural members.
    - **Construction Planning**
        - Initial construction plan considering material handling, urban constraints, and minimal traffic disruption.
        - Sequence and methods for excavation, tunneling, and platform construction.
- **Documentation and Graphics**
    - Conceptual renderings, cross-sections, and diagrams of proposed design.
    - Written narrative explaining design choices and addressing project challenges.

6. Evaluation Criteria

- Compliance with design requirements.
- Innovation in addressing space, structural, and urban constraints.
- Feasibility of construction plan.
- Clarity and completeness of design submittal.

APPENDIX J: COMMUNICATION WITH COMMUNITY PARNTERS

First Correspondence with Will Spielvogel and After Our First Meeting as Well (Received 08/29 - 08/31)

From: Joey Collentro <Joseph.Collentro@uvm.edu>
Sent: Wednesday, August 28, 2024, at 5:12 PM

Good Afternoon Mr. Spielvogel,

We are in the University of Vermont Senior Capstone Design Project, assigned to the Construction Industries of Massachusetts Student Design Completion. We were advised to reach out to you as our industry coach. We hope to set up a Teams meeting and hear from you within the next week. Our first available meeting would be this Friday August 30, after 3:30pm, as well as availability early next week.

We are excited to hear from you and learn more about this project.

Thank you,

Joey Collentro, Stites Allen, Megan Messina, Annie O'Hara

> **From:** willsi2430@gmail.com <willsi2430@gmail.com>
> **Sent:** Wednesday, August 28, 2024, 7:05 PM
>
> *Thanks for reaching out and I look forward to meeting everyone.*
> *Friday after 3:30pm is fine with me.*
> *Next week, I'm available Thursday, Friday and over the weekend.*
> *My schedule is usually pretty open, but this week and early next, I'm consumed (more like overwhelmed) dealing with aging parents.*
> *Have you all received any info on the Project? I received a pdf file with a brief overview. I can forward if you like - just let me know.*
> *My cell is ~~XXX-XXX-XXXX~~ and I almost always answer any time of day if you ever need anything.*
> *Feel free to email me any agenda items or any questions you wish to discuss at the meeting. That would be helpful for me.*
> *Thanks again and have a good evening,*
>
> *Will*
>
> **From:** willsi2430@gmail.com <willsi2430@gmail.com>
> **Sent:** Saturday, August 31, 2024, 7:20 PM
>
> *Good to meet y'all yesterday. Favor- if you try to convey information to me via teams, please send me an email notice that there is something in there to look at. I never check teams or use it. Thanks*
>
> *Also, if you decide to visit some MBTA stations - take a tape measure and try to measure such things as typical column sizes, girder spacing and sizes, spans and heights (unsupported lengths) of the major structural features - it will help a lot. I'm sure you could contact the engineering*

department at the MBTA and get copies of existing drawings and designs. They used to provide these to private developers as well.

Have a good weekend,

Will

Correspondence with Ken Pidgeon After Our First Meeting (Received 09/24/24)

From: Ken Pidgeon <kpidgeon@ecivt.com>
Sent: Tuesday, September 24, 2024 9:25 AM

Hi Blue Line Team,

I'm following up on our meeting of last week with a few items that I'd like to offer as suggestions and food for thought:

- *The photo below is a seal for a tunnel portal. This particular seal was made by Akkerman who I have a pretty good connection to. They are a tunneling equipment manufacturer and they do mostly smaller diameter tunnels. As we discussed in our last meeting, the tunnel should have a connection to the underground station that provides a seal to the subsurface soil and water pressures. And a seal, like in the photo, might be used in a slurry wall cast into the ground prior to the tunneling operations.*
- *This technical stuff is really cool and motivates us all. However, I'm thinking the Team should first be focused on developing their goals and a design schedule with milestones and deliverables. We'll want to set up the spring semester team to pick up on your momentum. Does this make sense? Maybe you've already thought about it.*
- *A second step would be to vet out the biggest challenges (and risks) for the project and figure out how to focus on resolving these issues and mitigating the risks. For example, how to construct a station in a busy urban neighborhood. Perhaps you've already started or done this. I suggest that you create a spreadsheet risk matrix that organizes these issues with comments, assignments, and eventually their resolutions.*
- *After the Team gets focused on their goals and the major technical challenges. I would like to set up a Teams meeting with a tunnel consultant friend of mine. I envision that the Team would come up with a list of questions for him. I could set up this meeting in the next week or so. Please give me some dates and times and I'll set it up.*
- *Later on, I could coordinate another meeting with Akkerman to discuss their seal design.*

Feel free to call or email me if you have any questions.

I can also be available to provide some advising at other times with relatively short notice.

Kenneth A. Pidgeon, PE
President
Email kpidgeon@ecivt.com

From: Megan Messina <Megan.Messina@uvm.edu>
Sent: Wednesday, September 25, 2024 4:03 PM

Hi Ken,
Thank you for reaching out and for the suggestions.
We currently are developing alternatives and a design schedule with milestones. Our next assignment requires us to evaluate the biggest challenges with our chosen solution. We are hoping to coordinate a meeting with you and Will Spielvogel in the next coming of weeks to discuss further into these topics.

Thank you,
Megan Messina and Team

More Information Given by Ken Pidgeon (Received 09/24/24)

From: Ken Pidgeon <kpidgeon@ecivt.com>
Sent: Friday, September 27, 2024, 6:43 PM

https://vulcanhammer.net/wp-content/uploads/2017/01/dm7_02.pdf

Hi Team,

A first step in the feasibility of a short slurry wall is a basal stability check which is similar to the bearing capacity of a footing, only opposite. Attached is a screenshot of the DM7.02 Figure 28 and a link to DM7. This is a really easy check. You will need soil unit weight and undrained shear strength. You will need to find some shear strength data for the soft clay zone at the bottom of the station level (likely below the over consolidated crust) or use an applicable ratio of shear strength to effective overburden stress (do some literature searching). DM7 shows a minimum safety factor of 1.5 for the basal stability but I would go to 2.0.

Kenneth A. Pidgeon, PE
President
Email kpidgeon@ecivt.com

Correspondences Between Will Spielvogel and the Team (Received 10/16/24)

From: Joey Collentro <Joseph.Collentro@uvm.edu>
Sent: Tuesday, October 16, 2024 9:25 AM
Hi All,
I wanted to provide a few updates

Current Status:
We are currently reviewing the feedback on our Alternatives Memo and making adjustments based on your input and advice. We appreciate the guidance, and we plan to finalize our selection for the best alternative next week.

<u>Questions:</u>
We are wondering if either of you have any information on any permits needed for a project like this in Boston?

<u>Next Week:</u>
Our progress presentation is scheduled for ***Monday, October 21, from 4:45 to 5:05 PM*** *via Teams with our professor. This will be a brief presentation covering our findings on the two alternatives we're evaluating: the concrete diaphragm wall and the sheet pile wall.*

<u>Final Presentations:</u>
We've also received the date for our final presentation of the semester, which will take place on ***Monday, November 18, from 4:30 to 5:00 PM****. Please let us know if you'll be able to attend, either via Teams or in person.*

If you have any questions, please feel free to let us know!

Best regards,
Blue Line Team

> **From**: willsi2430@gmail.com <willsi2430@gmail.com>
> **Sent**: Wednesday, October 16, 2024, 4:58 PM
>
> *Thanks for the update.*
> *I trust you saw some of the old photos in the team's folder of two jobs a block away from that site.*
>
> *The soil design values on that sheet of paper I shared were used on the sheet pile soe.*
>
> *As far as Permits, that may be more in Ken's wheelhouse from his experience at GEI.*
>
> *I believe the following are required:*
>
> *At a global project level - early in conceptual design process:*
> *Nothing can move forward until the completion of a FEIR. - federal environmental impact report. - this is critical to the job moving forward.*
>
> *The FEIR is the big one it should cover all impacts from the community, to pollution, to impacts on surrounding structures, to noise, vibration air pollution ADA requirements, archeology, endangered species,…*
>
> *The MBTA will be very involved in the early permits.*
>
> *Boston water and sewer commission and the other utilities will need sign offs for any utility relocations or temp utility supports.*
>
> *This is not a private job - so I doubt you need any street and sidewalk occupancy permits or construction permits.*

The contractor will need a national storm water discharge elimination and pollution permit (NPDES). And a permit to haul soil over the roads and a permit from BWSC to discharge construction water into the storm system. And a permit to obtain a water meter for potable water, and a temp power supply permit.

Other than the FEIR and utility company approvals - none of the other stuff is a big deal and will not be schedule critical.

On every project I have been involved with - including design - build - the FEIR is done before the project can even get funding or go to design. So - not usually part of the process. Not sure of the intent for this assignment.

Will

From: Ken Pidgeon <kpidgeon@ecivt.com>
Sent: Wednesday, October 16, 2024, 5:09 PM
Team:

Permits are generally way outside of my wheelhouse. It seems like Will has a good stab at them and I'm thinking that Prof Cota might be able to provide further insight.

I will comment on the sidewalk and street occupancy permits – Will is probably right but you might want to check with the City of Boston. Up here in Burlington, we pay these fees (which can be substantial) regardless of the project owner. Even a different department within the city will be charged. It sounds crazy but it's all about provide income to the DPW budget.

Ken

<u>Feedback from Will Spielvogel on Alternatives Memo (Received 10/14/2024)</u>
*The original feedback was sent via email as a word document. This feedback has been condensed into important notes, the entire feedback can be retrieved from by request.

- Replace shareholders with stakeholders
- Cost Constructability and Performance
- 2 years to construct
    - Not including permitting

Slurry Walls
- Cost 1200 per cubic yard (per will)
- Bentonite slurry not good in saltwater
    - Use attapulgite clay or synthetic polymers in replacement
- Long Life span, contractors in Boston know them well
- Strengths
    - Foundation for temp decking
    - Can be used as a permanent wall
    - Significantly reduced vibrations
    - Can minimize groundwater seepage
- Limitations
    - Cost
    - Problematic guide wall construction

    - Potential for panel collapse ß RISK
    - Requires experiences and skilled workers ß COST
    - Space for equipment
    - Slower installation
    - Might need prestabilization of the ground
    - Need more work to use as finish face

Tie Back Sheet pile Wall
- Cost: approx. $35 per square foot w/o bracing
- Installed via pile driving NOT Drilling
- Tiebacks
    - Do not use
    - Use cross lot bracing and corner bracing
- Construction
    - Pre-trench to get rid of constructions
    - Vibrate sheets into clay
    - Use diesel impact hammer to drive sheet into clay
- Strengths
    - Most cost effective
        - Sheets can be removed after construction, but won't be in this construction because in urban environment
    - Can use already cast sheets
    - Can waterproof station on outside
        - Better for water proofing
        - Lower maintenance costs
    - Minimal footprint for construction
- Limitations
    - Removal of deep obstructions during installation
    - Larger footprint
        - Sheet pile + outside wall of the station
    - Greater lateral deflection
    - Vibrations from installation could damage nearby structures
    - Noise from installation

Stages of Construction
- Retrenching, utility relocation and installing pedestrian control protections.
- vertical support of excavation wall installs and decking install
- mucking pit and bracing install
- permanent structure build

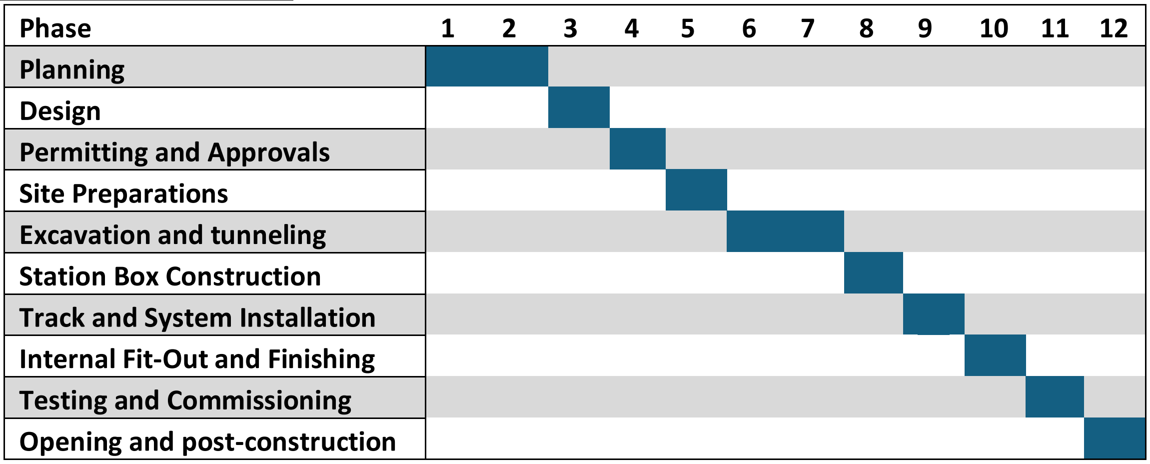
Ranking (in order)
- Construction Schedule
- Disruption
- User Accessibility
- Design
- Cost
- Maintenance Costs

Future Graphics
- Equipment Placing

- Traffic Divergence
- Pedestrian Divergence
- Table of all businesses in area as of right now

APPENDIX K: PROJECT TIMELINE

Gantt Chart of Milestones



Breakdown

Planning (2 Years)
- Initial Concept
- Review of existing infrastructure
- Cost estimation

Design (2 Years)
- Structural Design
- Tunneling Design
- Utility Design

Permitting and Approvals (2 years)
- Environmental Concerns (Environmental Impact Assessment) (12-18months)
- Permits and Regulations

Site Preparations (2 years)
- Surveys
- Utility Relocation

Excavation and Tunneling (1 – 1.5 years) (Main Focus)
- Tunneling via TBM method (18-30 months)
    - Do not need to do logistics of it, but part of timeline
- Install Slurry Wall
    - Steps For Slurry Wall Construction
        - Excavation
            - Materials / Machines needed?
            - Depth?

- Mixing
    - ~~Bentonite Clay~~ (Polymer Mix) mixed with water to create slurry. Mixing happens on site.
- Placement
    - Slurry is pumped into the trench. Compacted using vibratory compactor. Must solidify before next lift is placed
- Solidification
    - It takes a few days depending on the type of bentonite used and weather conditions in the area.
- Monitoring
    - Leaks and cracks?

Station Box Construction (2 years)
- Foundation Construction
- Concrete installation

Track and System Installation (2 Years)
- Track Laying
- Electrical and ventilation
- Signal and communication systems
- Drainage systems

Internal Fit-Out and Finishing (1 - 1.5 years)
- Platform construction
- Interior finishing
- Install gates and signs

Testing and Commissioning (1 - 1.5 years)
- Systems Testing
- Track and train testing
- Final Inspections and final approval

Opening and post-construction (6 months – 1 Year)
- Grand Opening
- Monitoring and maintenance.

Potential Risks
- Geotechnical Risks
- Environmental
- Budget
- Extended Scope
- Engineering
- Construction
- Legal
- Safety
- Maintenance
- Public Relations