CITY OF
FORT LAUDERDALE

Memorandum

Memorandum No: 23-114

Date: September 18, 2023

To: Honorable Mayor, Vice Mayor, and Commissioners

From: Greg Chavarria, City Manager Greg Chavarria (Sep 19, 2023 13:33 EDT)

Re: **New River Crossing – Mooney Consulting Final Report**

In May 2023, the City of Fort Lauderdale procured the services of Mooney Consulting to further evaluate the New River passenger rail crossing alternatives. Dr. Michael A. Mooney, PhD, P.E. is the Bruce E. Grewcock Distinguished Chair Professor of Underground Construction & Tunneling and of Civil Engineering at the Colorado School of Mines. Dr. Mooney has extensive experience in teaching, research, and consulting focused on the planning, analysis, design, construction, monitoring, and information engineering of tunnels and underground infrastructure.

The Mooney Consulting scope of work included the following tasks which were memorialized in the attached report.

- Task One: Independent assessment of existing feasibility study findings with consideration for advances in tunneling technologies and recent performance achievements in tunnel construction.

- Task Two: Technical review of tunnel and single station aspects not considered in feasibility studies, e.g., alternative construction methods, depth, cross section, single bore vs. dual tunnels.

- Task Three: Comparison of bridge vs. tunnel life cycle cost factors and environmental factors to consider, including related to design service life differences, maintenance and rehabilitation, noise, surface disruption differences, etc.

- Task Four: Other miscellaneous aspects regarding tunnel construction, e.g., geotechnical risk, words of wisdom, reference to other bridge vs. tunnel studies and outcomes.

If you have any questions, please contact Ben Rogers, Director of Transportation and Mobility at 954-828-3781 or brogers@fortlauderdale.gov.

Attachment: Mooney Consulting Final Report

c: Anthony G. Fajardo, Assistant City Manager
Susan Grant, Assistant City Manager
D'Wayne M. Spence, Interim City Attorney
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Patrick Reilly, City Auditor
Department Directors
CMO Managers

Michael Mooney Consulting, LLC
Golden, Colorado 80403

September 15, 2023

Ben Rogers, Director
City of Fort Lauderdale

Re: New River Crossing study

Dear Ben,

Please find herein a summary of my findings resulting from the following four tasks:

1. Independent assessment of existing feasibility study findings with consideration for advances in tunneling technologies and recent performance achievements in tunnel construction.
2. Technical review of tunnel and single station aspects not considered in feasibility studies, e.g., alternative construction methods, depth, cross section, single bore vs. dual tunnels.
3. Comparison of bridge vs. tunnel life cycle cost factors and environmental factors to consider, including related to design service life differences, maintenance and rehabilitation, noise, surface disruption differences, etc.
4. Other miscellaneous aspects regarding tunnel construction, e.g., geotechnical risk, words of wisdom, reference to other bridge v. tunnel studies and outcomes.

Overall, I find that further consideration should be given to the larger (42-45 ft diameter) single bore tunnel to house two rail lines and the Fort Lauderdale station. The use of the larger bore as a significant component of the Fort Lauderdale station has not been considered in the reports. I suspect that the schedule and therefore cost benefits of the larger single bore have not been properly considered, nor has the considerable reduction in surface impact that a larger single bore tunnel would have over a cut-and-cover station or elevated structures. I find that the 5:1 capital cost ratio of the tunnel option to high level bridge option is inflated as is the operating cost ratios reported. The $3B+ capital cost estimate for the larger single bore tunnel (2020 Corradino Goup report) and station seems to be high in comparison to recent tunnel data (outside NYC), including the Port of Miami tunnels. A closer examination of similar large bore transit projects in Barcelona and Toronto is waranted. The $3.3B estimated operating cost of the tunnel over 50 years (2023 Whitehouse Group report) appears overestimated in my view. The difference in bridge design service life (75 yrs) and tunnel design service life (125-150 years) has not been factored in, nor has the economic, aesthetic, quality of life and public health benefits of undergrounding rail service (compared with elevated structure). To this end, given the changing dynamics and future priorities of urban life, I find the up front capital cost-only framework for comparing alternatives as incomplete and biased against underground options.

A more detailed documentation of my findings is provided on the following pages.

Summary of Project Background and Documents Reviewed
I reviewed a number of documents, presentation files and recordings made available at the project website.[1] My understanding of the critical documents and the chronology of the study is as follows:

- A New River crossing feasibility study was completed by the Corradino Group and HDR for FDOT, and is memorialized in a Jan. 2020 report[2].
- The feasibility study evaluated four alternatives, including (1) a low-level bascule bridge, (2) a mid-level bascule bridge, (3) a high-level fixed bridge and (4) a single 7,085 ft long, 38 ft inside diameter tunnel. Alternative 1 would include 1.1 miles of improvement; options 2-4 would require 2.5 miles of overall improvements. The report included a high level cost estimate for each alternative.
- FDOT issued an Initial Draft Opinion of Probable Cost Estimate[3] developed by HDR in Dec. 2021 for twin 23 ft inside diameter tunnels, each extending 9400 ft in length.
- The BCR PD&E Study issued a pdf of a Virtual Alternatives Public Workshop presentation delivered Jan. 27, 2022[4] that provided information about the four alternatives, including drawings and schematics showing the twin 23 ft inside diameter tunnels. In addition, the BCR PD&E student provided a series of complementary exhibits on its website[5]. I was unable to find any documented record of basis for the FDOT shift from a single 38 ft ID tunnel to twin 23 ft ID tunnels.
- In addition to this information, I have reviewed a report from the Lochner/LBA Partnership issued March 1, 2023[6] and a report from Whitehouse Group issued Aug. 17 2023.[7]

1. **Independent assessment of existing feasibility study findings with consideration for advances in tunneling technologies and recent performance achievements in tunnel construction.**
2. **Technical review of tunnel and single station aspects not considered in feasibility studies, e.g., alternative construction methods, depth, cross section, single bore vs. dual tunnels.**

Given the blending of single vs. twin tunnels as well as tunnel depth in the 2020 and 2022 reports, I will address tasks 1 and 2 together.

A 42 ft excavated (bored) diameter, 38 ft finished (inside) diameter tunnel was proposed in the 2020 Corradino group feasibility report (Fig. 1). The vertical alignment shows this single tunnel as passing 5 ft beneath the New River crossing (Fig. 1). Twin 25 ft excavated diameter, 23 ft inside diameter tunnels were proposed in the 2022 PD&E presentation. The vertical alignment show these twin tunnels as

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1 https://www.fdot.gov/projects/broward-commuter-rail-south/documents-and-publications.
2 New River Crossing Feasibility Technical Memorandum, prepared by Corradino Group, Jan. 2020, 296 pp., accessed at https://www.fdot.gov/projects/broward-commuter-rail-south/documents-and-publications.
3 Initial Draft Opinion of Probable Cost Estimate v1.0, FDR, Dec. 3, 2021, 43 pp., accessed at https://www.fdot.gov/projects/broward-commuter-rail-south/documents-and-publications.
4 Virtual Alternaties Public Workshop presentation, Jan. 27, 2022, 74 pp., accessed at https://www.fdot.gov/projects/broward-commuter-rail-south/documents-and-publications.
5 Alternative Public Workshops exhibits, Jan. 27, 2022, accessed at https://www.fdot.gov/projects/broward-commuter-rail-south/documents-and-publications.

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passing 25 ft beneath the New River crossing (Fig. 2). The tunnel lining would be on the order of 18 in. thick for the single tunnel and 12 in. thick for the twin tunnels. The twin tunnels option requires nine cross passages to provide emergency egress. Cross passages are constructed by manual excavation (termed the sequential excavation method, SEM) that is time consuming and introduce risk of surface deformation (settlement) and building/utilities damage.

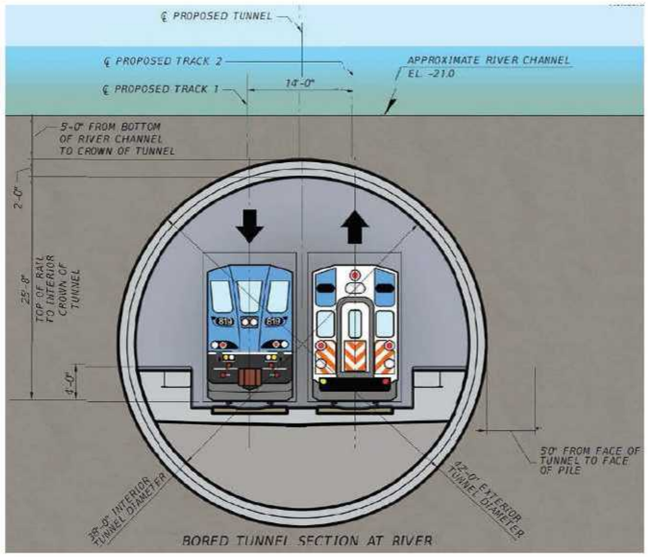


Fig. 1. Proposed 42 ft bored diameter, 38 ft inside diameter tunnel in 2020 Corradino Group feasibility report. Cross-section shown at the New River crossing.

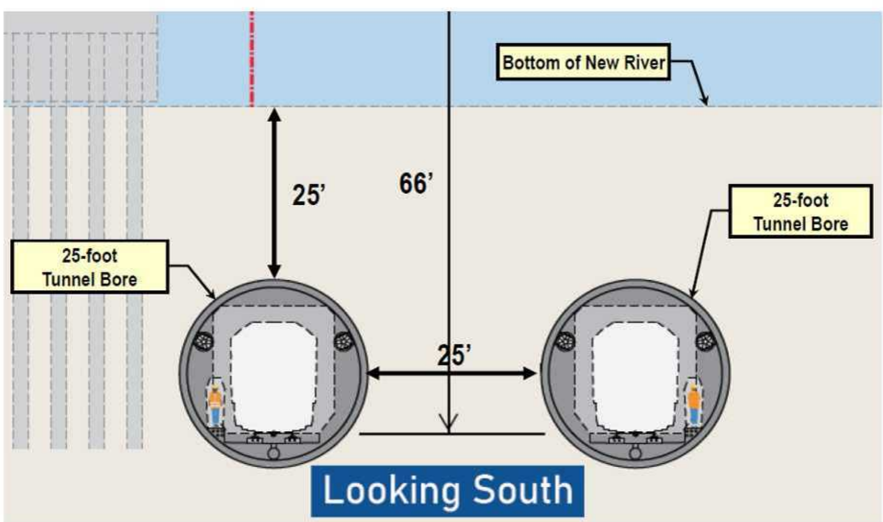


Fig. 1. Proposed 25 ft ft bored diameter, 23 ft inside diameter tunnel in 2022 PD&E public workshop presentation. Cross section shown at the New River crossing.

Geotechnical Considerations

Geotechnical conditions were not discussed in either the 2020 feasibility study or in the 2022 PD&E presentation. The tunnel depth reaches EL -70 ft (below MSL) and the station EL -80 ft in both the 2020 and 2022 conceptual profiles. A 2021 geotechnical investigation performed by Quest along Las Olas Boulevard (with two borings near the proposed tunnel alignment) reveals interbedded layers of sand, limestone and sand with limestone fragments to the sampling depth of 100 ft (EL -95 ft below MSL). Two boring logs B6 and B7 are generally in the vicinity of the tunnel alignment. Of note is that the sand is loose to medium dense and appears from the surface to EL -40 to -50 ft. Below this, there are 10-20 ft thick layers of limestone and 15-20 ft thick layers of sand in a layer cake arrangement. A TBM would therefore predominantly encounter mixed face conditions (sand and limestone) with some full face sand conditions if deeper. The presence of a 12-20 ft thick limestone layer beginning at EL -45 to -50 ft could provide an important stabilizing layer above the TBM. Laboratory test data was not provided in the report nor are there remarks about karstic features in the limestone (i.e., voids).

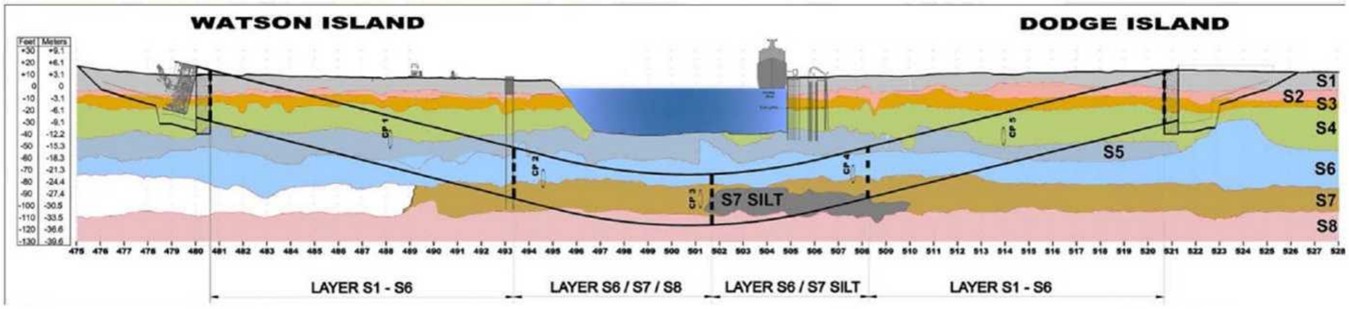
The ground conditions likely warrant that a slurry pressure balance or variable density TBM (if karst is probable) be used to maintain face pressure control in water-saturated sand and limestone with potential voids. With these shallow tunnels, slurry pressure balance is capable of providing consistent ground support leading to very little (inconsequential) overlying settlement of structures and railroad lines, e.g., a few mm. The Queens Bored tunnel project under the Sunny Side railroad yard is a good example of slurry pressure balance TBM performance[8]. Twin 25 ft diameter slurry pressure balance TBMs tunneled within one diameter of the surface under active train tracks while maintaining a few mm of settlement and heave. The Fort Lauderdale ground conditions are not similar in that the Queens soils were stiffer; however, slurry pressure balance is capable of very good ground deformation control in Fort Lauderdale type ground conditions. Additional ground investigation, including grain size distribution analysis, is necessary to further define the suitability of slurry pressure balance tunneling. If there were considerable fines content (silt and smaller) and if karstic voids were not present, earth pressure balance (EPB) TBM tunneling might be an option. EPB TBM tunneling is more common and less expensive than slurry pressure balance TBM tunneling; however, the risk of ground surface deformation is greater with EPB.

The relationship between the ground conditions in Fort Lauderdale and those encountered during the Port of Miami tunnel is worth mentioning. As shown in Fig. 3, the 42.5 ft excavated diameter Port of Miami TBM reached EL -115 ft. Considerable grouting was required prior to tunneling to fill voids in the highly karstic coralline limestone (S7 in Fig. 3). A dual mode TBM was used on the project. Earth pressure balance (EPB) was used for the left and right thirds of the tunnel (nominally) and water pressure balance was used in the S7 material. The water pressure balance approach inspired the variable density configuration used today in shallow porous ground like south Florida. There is no evidence of highly karstic conditions in Fort Lauderdale that would require pre-excavation grouting; in fact, the variable density TBM technology often precludes the need for such pre-excavation grouting.

It is also worth noting that the Port of Miami TBM excavated less than one diameter below the ship channel. The depth of tunnel under the New River crossing is important as it dictates the length of the tunnel and portal to the south. The shallower the tunnel, the less length of tunnel/portal to the south. The 2020 report shows the 42 ft outside diameter TBM tunnel just 5 ft below the river (Fig. 1) while the 2022 report shows the 25 ft outside diameter twin tunnels as 25 ft below the river (Fig. 2). Tunneling with 5 ft of cover is on the extreme end, would require ground improvement of the river channel via

[8] Mooney, M.A., Grasmick, J.G., Kenneally, B. and Yong, F. The Role of Slurry TBM Parameters on Ground Deformation: Field Results and Computational Modeling. Tunnelling & Underground Space Technology, 2016, 57(8), 257-264, https://doi.org/10.1016/j.tust.2016.01.007.

grouting, and would create bouyancy concerns for the tunnel, i.e., air-filled tunnel wanting to rise. That said, the New River crossing is a very short span and therefore, construction beneath it could be tightly controlled. It is likely that this cover depth would need to be increased from 5 ft, and further detailed analysis is required to determine what depth. I do feel that 25 ft cover depth is conservative for either the 25 ft TBM tunnel or the 42 ft TBM tunnel, and that a reasonable solution can likely be developed for a cover depth in the 10 ft range.



Soil Layer	Geological Description	Strata Description
Layer S1	Man-Made Deposits	Reclamation/Dredged Limestone Fill
Layer S2	Coastal Sediments	Sand, Silty Sand and Silt
Layer S3	Miami Limestone	Weakly cemented limestone with fine sand
Layer S4	Transition Zone	Siliceous sand, limestone / cemented sand layers
Layer S5	Fort Thompson Formation	Moderately to strongly cemented, fine to medium-grained sandy Limestone (UCS 1.5-35.5MPa)
Layer S6	Anastasia Formation	Cemented Shell / Cemented Sand (Coquina) (UCS 2.4-24.2MPa)
Layer S7	Key Largo Formation	Coralline limestone, heavily dissolved and highly porous (coral and limestone fragments weakly to very weakly cemented with calcarenite with zones of uncemented fragments and sand lenses)
Layer S7 SILT		Lime Silt with varying amounts of limestone fragments
Layer S8	Tamiami Formation	Limestone and Sandstone with interbedded lenses of cemented sand, cemented shell and sand (UCS 0.9-35.9MPa)

Fig. 2. Ground conditions for the Port of Miami tunnel as shown during my presentation to the Miami-Dade County Geo-Institute Chapter in March 2023 (figures/table courtesy of Bouygues-CBNA).

Single Bore Tunnel vs. Twin Bore Tunnels

TBM-based construction was assumed in the 2020 and 2022 reports. This is reasonable given the distances (7,085 ft for single tunnel including station length and 9,400 ft x 2 for the twin tunnels) and given the high groundwater table, the sandy conditions and the need to tightly control ground deformation. Conventional excavation via the sequential excavation method (SEM) is often selected for tunnel lengths on the order of 0.5 miles or less. SEM would be very challenging in the high groundwater table and permeable ground of Fort Lauderdale, and would introduce greater risk of construction-induced structural damage than would TBM tunneling.

The twin 25 ft excavated diameter tunnel arrangement proposed in the 2022 report is based on decades of precedence with similar arrangements. The twin tunnel arrangement does require cross passage construction for emergency egress via the sequential excavation method (SEM) that is essentially a hand mining approach. The 2022 report estimated that 9 cross passages are required. The sand between the two tunnels will need to be frozen or grouted to enable stable cross passage construction. A similar approach to this was performed during construction of the twin Port of Miami tunnels. The process of cross passage construction can be challenging and time consuming, and this effort cannot generally take place until after the main tunnels have been completed. Therefore, the cross passage construction during twin tunnel approach lengthens the project, e.g., can be on the order of 3 additional months per cross passage).

A single larger bore approach housing two train lines is increasingly being adopted for commuter rail and light rail transit service. For example, the 45 ft exavated diameter Scarborough line in Toronto is under construction, the 53 ft excavated diameter BART to San Jose extension is under final design and pre-construction planning in San Jose, and LA Metro is considering a single 40 ft diameter tunnel for the upcoming Sepulveda transit project. Fig. 3 depicts these single bore concepts already constructed (Barcelona), under construction (Toronto), and in design (San Jose). The single bore tunnel housing two train lines with central structural wall separation and emergency egress doors (wall separation not depicted in the 2020 report) would provide sufficient fire life safety.

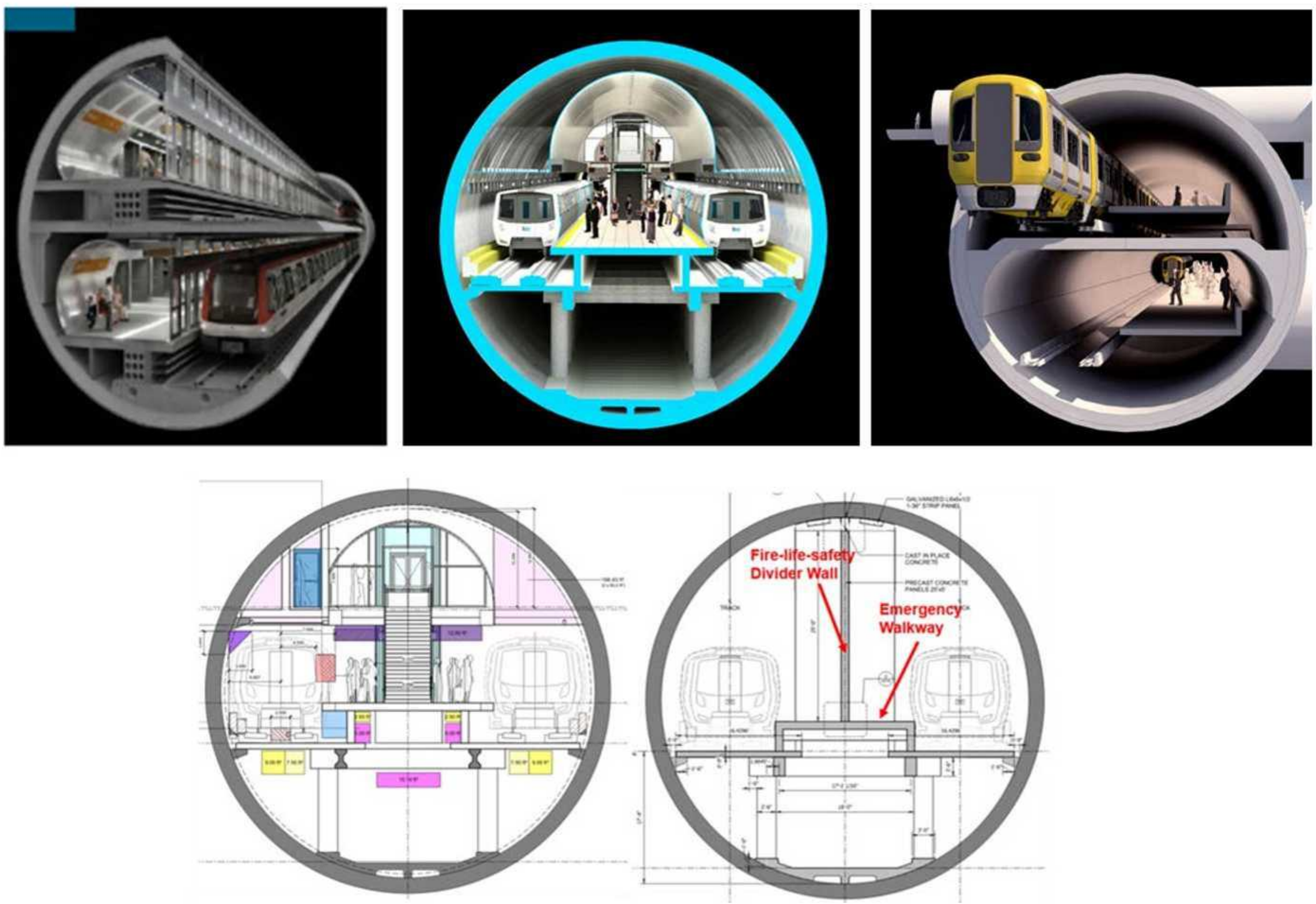


Fig. 3. Single bore tunnels housing two trains: Barcelona (top left), San Jose (top middle), Toronto (top right). Cross-section for San Jose station (bottom left) and running tunnel with divider wall and emergency walkway (bottom right).

The US tunneling industry is increasingly adopting large diameter tunnels, and the level of experience with large diameter TBM tunnel construction has grown in the US. In addition to the aforementioned projects and the 42.5 ft diameter Port of Miami TBM, there are two roadway tunnel projects under construction in Virginia that are in the 45 ft excavated diameter range. The Chesapeake Bay-Bridge Tunnel project involves an EPB TBM while the Hampton Roads Bay-Bridge project involves a variable density TBM. For perspective, the largest TBM in the US was the 58 ft diameter EPB TBM used to construct the Alaskan Way tunnel in Seattle from 2012 to 2018. The largest in the world is the 59 ft diameter slurry pressure balance TBM used to construct the Tun Mun – Chep Lak Kok twin roadway tunnels in Hong Kong during the same time period.

In my experience, the production rate of the larger 40+ ft diameter TBMs is approximately 60-70% of the excavation rate of 25 ft diameter TBMs. Also, cross passages are not needed for the larger diameter single tunnel. For schedule comparison, consider the 9400 ft long horizontal extent of twin tunnels proposed in the 2022 study. Assuming that construction time and effort for portals and initial TBM setup is similar for the single 42 ft TBM tunnel vs. twin 25 ft TBM tunnels, and assume a 1000 ft per month production rate for a 25 ft diameter TBM (based on average 50 ft/day x 20 days/month). A single 25 ft diameter TBM would require 9.5 months for each tunnel plus 4 months of TBM transition time between tunnels. In addition, twin tunnels would require the construction of cross passages that could be 1-2 years after tunnel completion. This total excavation time = 23 months, and closer to 3 years (36 months) considering cross passage construction. Of course, one could consider two TBMs but this is not typical for this tunnel length. Normally, a single TBM would be used for this combined tunnel length. And, one could argue that track and systems work could occur simultaneously with some cross passage work but there are complications in this approach (clash of operations, different contractors).

The 42 ft diameter TBM production rate would be 700 ft/month (assuming 70% of the 25 ft diameter TBM), and therefore would require 13.5 months. No cross passages and TBM reconfiguring are required). Therefore, the single larger TBM creates the potential for considerable time and cost savings.

The larger single bore approach offers considerable potential benefit to twin tunnels when it comes to the station because the single bore is large enough to incorporate the majority of the station, e.g., platforms. This is further discussed in the following section.

Station Construction

A 1200 ft long by 72 ft wide by 90 ft deep cut and cover excavation is proposed for the station in the 2022 presentation report. This essentially involves a large box excavation the length of four football fields in downtown Fort Lauderdale that would be extremely disruptive. This approach also brings into play significant interaction with existing utilities that introduces considerable cost risk.

A more recent trend in transit construction is to create smaller surface footprint stations off to the side of the tunnel, and as described above, use the larger single bore to house the station platforms. See Fig. 4 for an example comparison. This greatly reduces surface disruption and utility risk.

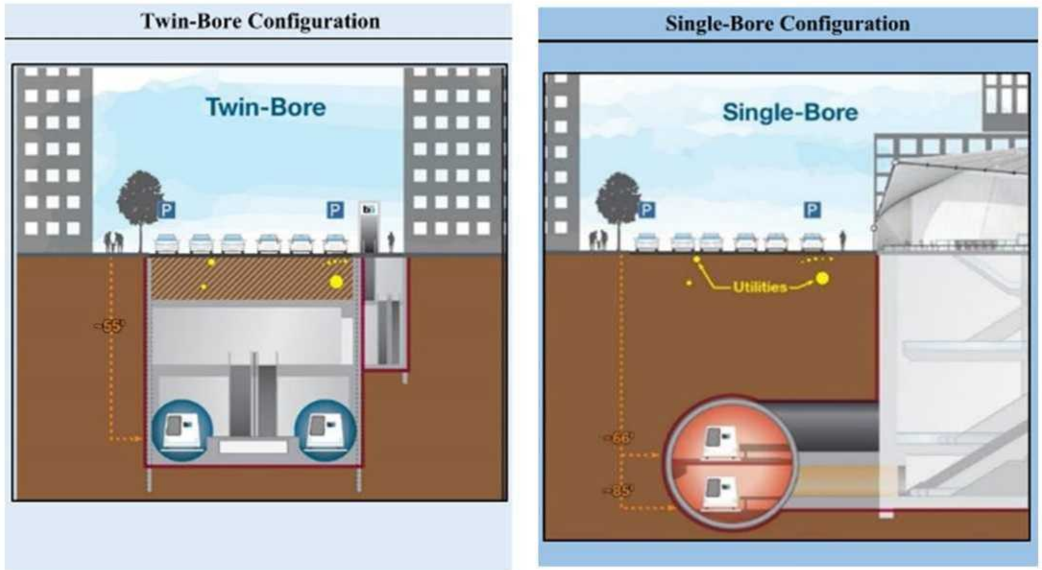


Fig. 4. The left side twin bore configuration, similar to that proposed in the FDOT study, involves lengthy (inth the page) cut and cover construction through overlying utilities. The right side single bore configuration avoids the utilities and builds off-to-the-side shorter length (into the page) structures to access the platforms that are constructed within the bored tunnel. Images here from the BART to San Jose tunnel project currently under final design.

Figure 5 shows rendered designs for the Toronto Scarborough line and the BART to San Jose line where the station platforms are constructed within the single bore tunnel and the surface access to the trains is minimal. This is a significantly different and less disruptive approach than the 1000 ft long cut and cover station proposed in the FDOT studies.

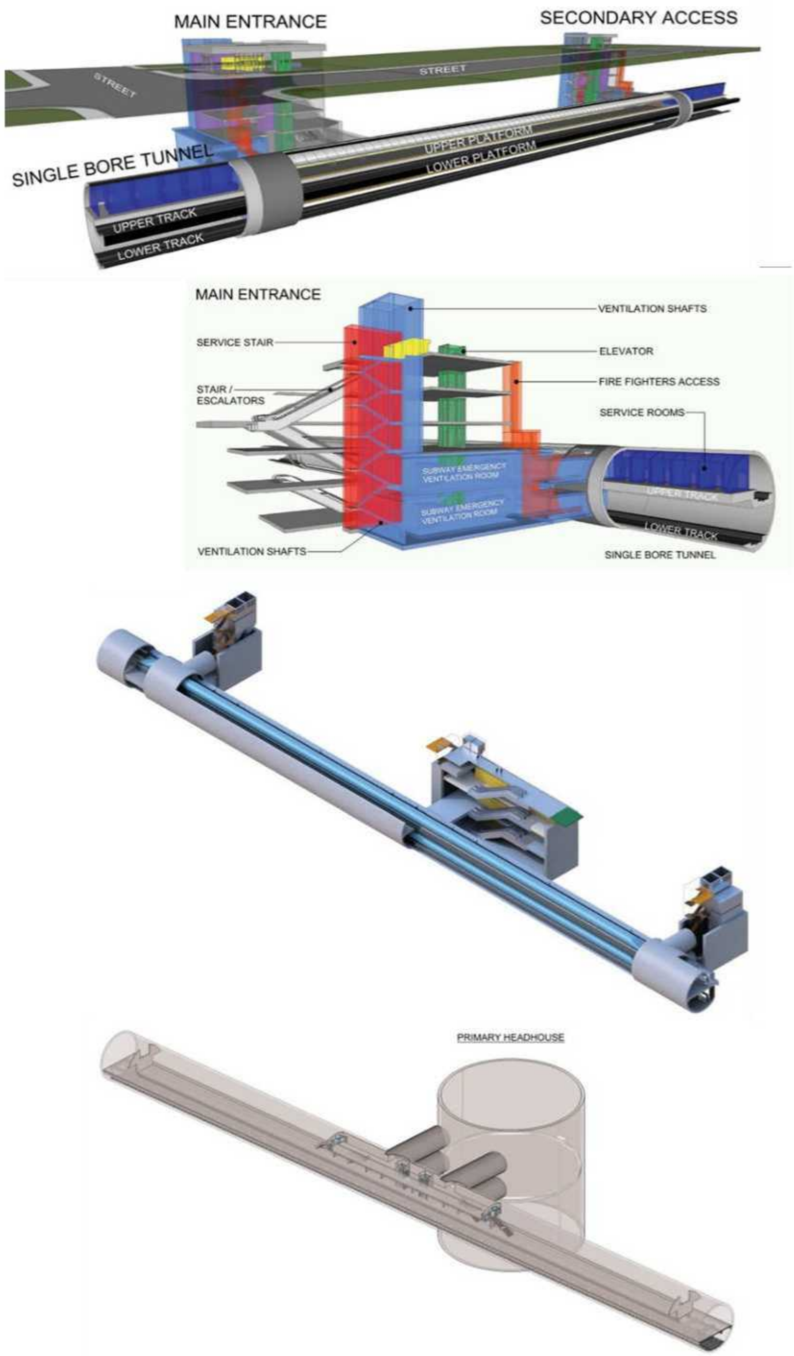


Fig. 5. Example station configurations (Toronto Scarborough Line top three, BART to San Jose Line bottom) for larger single bore tunnels where surface access and disrpution is minimized.

In the projects stated above, the station design, e.g., platform size, typically defines the diameter of the overall tunnel. Careful assessment of this is required but this would likely be larger than the 38 ft ID proposed in the 2020 report. The 35 ft wide platform and 67 ft overall ID width conveyed in the 2022 report extends beyond bored tunnel capability; however, this width can be reduced considerably through optimization like has been done in San Jose, Toronto, Barcelona, etc. Alternatively, the station could be expanded from the existing single bore tunnel using SEM construction techniques, all done from within the bored tunnel without surface and utility disruption.

If the 1200 ft long by 72 ft wide by 90 ft deep excavation cut and cover is pursued as shown in the 2020 report, the final structure would be 52 ft tall, with 36 ft of backfill. This final depth would fall in the vicinity of water permeable sand that would require jet grouting at the excavation base to seal off the groundwater prior to excavation. This grouting campaign would be extensive and would be required from the ground surface – thus closing off traffic.

Cut and cover station excavation is highly disruptive at the ground surface. If performed traditionally with a bottom-up approach, the entire footprint would be closed to surface activity, e.g., traffic. Jet grouting would be performed from the surface, followed by slurry or secant pile wall construction, followed by excavation, construction of the permanent reinforced concrete station, backfilling and return of the surface to its intended function. This can present years of closure and would be very disruptive to surface activity, traffic, etc.

More recent approaches, for example during recent LA Metro station construction, involve top down staged construction wherein the perimeter structural walls are constructed and sections of the road are excavated to depths of 10-15 ft, spanned with girders, overlaid with steel plate, and returned to service using night and week-long level of service periods. Careful planning and sequencing would be needed to coordinate jet grouting within this approach. This approach of design and construction planning places high value on maintaining surface level of surface and minimizing surface noise, dust, disruption, etc. Top down construction is more expensive than bottom up construction. If a full cut and cover station construction approach is to be pursued for Fort Lauderdale, top down construction is recommended given the benefits to city surface operations and quality of life during construction.

3. **Comparison of bridge vs. tunnel life cycle cost factors and environmental factors to consider, including related to design service life differences, maintenance and rehabilitation, noise, surface disruption differences, etc.**
4. **Other miscellaneous aspects regarding tunnel construction, e.g., geotechnical risk, words of wisdom, reference to other bridge v. tunnel studies and outcomes.**

Regarding cost, the 2020 Corradino report provided a preliminary cost estimate of $3.3B for the single bore 38 ft ID tunnel alternative that included $500M in design contingency and $250M in construction contingency (30% overall contingency). The final tunnel cost for slightly longer than one mile (estimated for 5400 ft length) of single tunnel planning, design and construction (including 36% professional services) was estimated at $1.6B and the cut and cover station was estimated at $1.4B. This 2020-basis tunnel cost estimate is on the high end for US tunneling. With the exception of NYC tunneling costs (has been up to $2.5B/mile), US tunnel costs range from $600-$900M[9], placing the $1.6B/mile estimate for the New River cross tunnel considerably greater. The total cost for the slightly larger diameter Port of Miami tunnels that spanned 1.5 miles combined was $350M ($230M/mile) in 2014 dollars (the overall total P3 contract was $710M), a significantly lower cost than the New River crossing tunnel estimate, even considering inflation. The $1.4B cost estimate for the station could be reduced

[9] Munfah, N and Nicholas, P. "The cost of tunnneling," Tunnel Business Magazine, https://www.mydigitalpublication.com/publication/?i=670100&article_id=3740162&view=articleBrowser

considerably via station integration with a single large bore tunnel as described above. The new construction area/volume could be notably less than the proposed cut and cover station.

The 2021 HDR cost estimate for the twin tunnels and cut-and-cover station was $1.8B, including 25% contingency. Notable differences between the single bore and twin bore cost estimates lie in the station estimate ($1.4B for the single bore vs. $650M for the twin bore) and professional services ($865M for single bore + station vs. $336M for twin bore + station). The twin bore tunnel cost estimate considers a single TBM and construction of cross passages that must wait until the tunnels are complete. It is my view that a more detailed cost analysis is required for the larger single bore tunnel, including consideration of the station approach followed by the large bore tunnels in Barcelona, Toronto and San Jose.

Regarding maintenance and operations (M&O) cost, I note considerable disagreement between that stated in the 2020 Corradino report ($8.2M per year) and the 2023 Whitehouse report ($3.3B over 50 years). The latter seems quite high particularly when considering the reported 60:1 M&O cost ratio of high level bridge to tunnel. Also of note is lack of consideration for the 125-150 year design service life of tunnels compared to the 75 year design service life of bridges. Similar M&O cost factors have been reported for bridges and tunnels in NYC through 50+ years but thereafter bridge M&O costs noticeably increase while tunnel M&O costs did not.[10]

Regarding other miscellaneous aspects, the following general points are offered for consideration.

- Underground construction is designed to be significantly less disruptive during construction than surface or bridge construction. With a single large bore tunnel, the surface impact would be felt at the north and south portals only, as well as at small footprint locations where access to the underground station (within the tunnel) is provided. If priority is given to minimizing construction impact, an underground solution can be conceived and planned with care and attention to dramatically minimize impact during construction, much moreso than surface and elevated construction.
- One challenge associated with tunnel construction is the transport of the excavated ground. This is often done by truck hauling that can be disruptive to the local community. The proximity of the freight rail lines immediately adjacent to the portals enables the opportunity to transport the excavated earth away from the downtown area via rail, avoiding dump truck traffic on Fort Lauderdale city streets.
- The Whitehouse Group report conveyed that Brightline indicated a cut-and-cover station to be undesirable and that FEC conveyed there would be an "astronomical" amount of utilities to deal with. As I summarize above, a cut-and-cover station approach can be replaced by a large bore tunnel with much smaller and offset surface structures. Such an approach can be designed to avoid impact with the existing Brightline station and to greatly minimize utility interaction.
- Tunnels are routinely designed to 150 year service lives. The design life of bridges are considerably shorter. For example, FDOT requires bridges to be designed for a 75 year design service life. While the use of initial design and construction cost approach has merit from a cash flow and funding allocation perspective, the life cycle cost analysis makes a significant difference when considering the design service life.
- Maintenance costs for underground infrastructure are less than elevated structures. The infrastructure underground, e.g., concrete, rails, ties, systems, etc., remains at a constant temperature and is not exposed to weather. All of these aspects are exposed to the elements for an elevated structure.

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[10] Zhang, et. al., Life cycle cost analysis of bridges and tunnels, Proc. 2005 Construction Research Congress, 12 p. accessible at https://ascelibrary.org/doi/10.1061/40754%28183%2926.

- Underground infrastructure requires mechanical and electrical equipment for fire-life safety (fire suppression) and ventilation that is not necessary for the elevated options (except at the station). Such equipment has a lifespan of 20-30 years and does require maintenance; however, such costs are quite manageable for the myriad transit agencies that operate tunnels.
- The concrete quantity, and thus embodied carbon footprint, of elevated structure options is greater than for the tunnel option. As carbon taxing and carbon offset requirements grow, this factors in favor of the underground option.
- A tunnel offers better protection against the forces of weather than a bridge structure, e.g., hurricane-force winds.
- Flood risk is notably higher for a tunnel and this must be considered carefully when designing the tunnel. The elevations of the portals should be designed to consider future sea level and flood levels, flood gates should be considered, and sufficient pumping systems should be in place to remove water. There is no reason why a flood control system, with redundancy built in, cannot keep tunnels operational. Many tunnels around the US and internationally have solved this challenge.
- Quality of life for people living and working in the vicinity is improved for underground infrastructure than overlying infrastructure in terms of noise, pollution due to emissions, aesthetics, and safety. There are a number of studies that have scientifically documented the negative affects of environmental noise, including that from commuter trains[11,12].

As a summary thought, urban areas are undergoing significant change prompted by the increase in urban population density, greater desire for improved quality of urban life including lower noise, more green/natural space, etc., social/environmental justice, and multi-modal transportation including micro mobility, autonomous vehicles, etc. These drivers all point towards moving transport of people and goods underground. For Fort Lauderdale, the capital cost to build underground is higher than elevated structure. Whether this is a 5:1 cost differential as suggested in the reports vs. a 2:1 to 3:1 ratio that is more typical, building undeground requires higher up front capital investment. This cost differential decreases further when considering sustainability, quality of life, noise, aesthetics, difference in design service life, life cycle cost analysis, etc. The value of all of these attributes can tip the balance considerably towards underground. Finally, I understand that relocating the existing freight rail lines underground is not being considered and not desired by the FEC. However, it is worth mentioning that benefits summarized above are significantly amplified if the existing FEC freight rails can be moved underground adjacent to the planned commuter rail lines.

Sincerely,

Michael A. Mooney

Michael A. Mooney, PhD, PE

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[11] Swinburn et al., "Valuing Quiet: An economic assessment of US environmental noise as a cardiovascular health hazard, Am J Prev Med. 2015 Sep; 49(3): 345–353. Accessible at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4819987/#:~:text=The%20analyses%20suggest%20that%20a,is%20estimated%20at%20%243.9%20billion.

[12] Tsaligopoulos, A., "Approaching Quietness as an Urban Sustainability Opportunity," Environments 2022, 9(2), 12, https://www.mdpi.com/2076-3298/9/2/12