Dulles Corridor Metrorail Extension Project—Tunneling Options for Tysons Corner

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ABSTRACT: Metropolitan Washington Airport Authority is currently undertaking the first Phase of Metro's Extension to Northern Virginia. A wide range of tunnel options was considered for the Tysons Corner segment that involves about 20,000 feet of track and four stations. After consideration of many options that involved EPBM single track tunnels, NATM tunnels and large bore tunnel concepts for the entire Tysons alignment, the design now being progressed into construction involves two 520 meter (1,700 feet) long soft ground NATM tunnels with several hundred feet of cut-and-cover construction. The paper discusses the process that led to selection of the short NATM tunnels as the most feasible of the options considered for Tysons.

INTRODUCTION

The Dulles Corridor Metrorail Project will extend Washington Metropolitan Area Transit Authority's (WMATA) rail services from the Metrorail Orange Line in Fairfax County, Virginia to Route 772 near Ashburn in eastern Loudoun County. This corridor encompasses several activity centers including Tysons Corner, Reston, Herndon, and International Airport Dulles (IAD) as well as emerging activity centers in eastern Loudoun County. The project alignment within the Dulles Corridor is displayed in Figure 1.

The implementation of the project began with preliminary engineering in mid 2004 under a public private partnership agreement between Virginia Department of Rail and Transportation (DRPT) and Dulles Transit Partners (DTP), the Bechtel led design-builder of this project. Other partners in financing the project and approving the engineering for the design-build effort are the Federal Transit

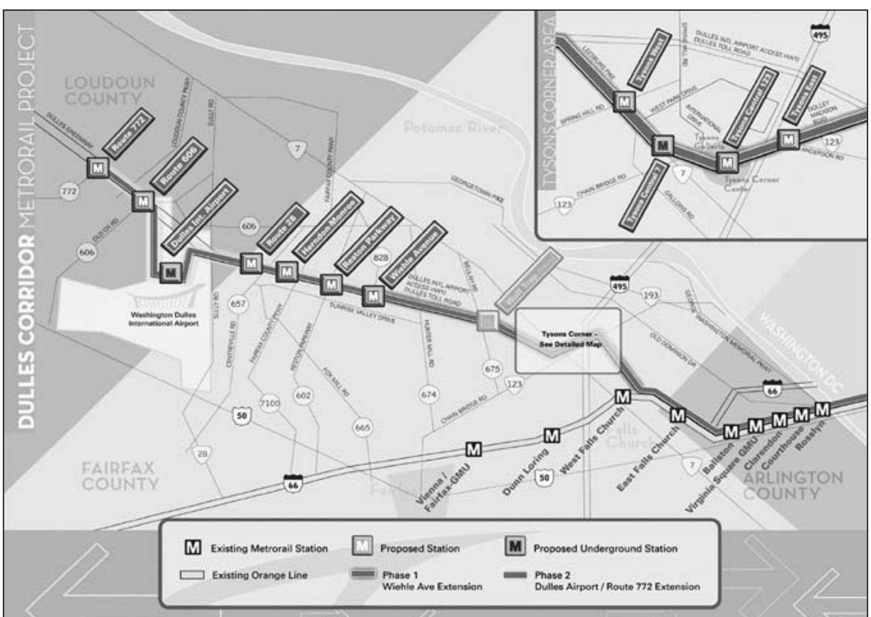


Figure 1. Dulles Corridor Metrorail Project

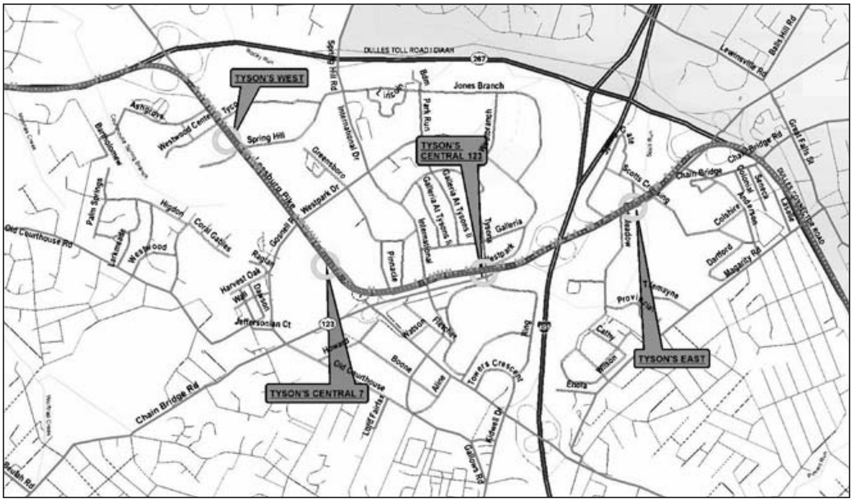


Figure 2. Metrorail at Tysons Corner in McLean, Virginia

Administration (FTA), the Metropolitan Washington Airports Authority (MWAA), County of Fairfax, and Loudoun County, the towns of Reston and Herndon and Washington Metropolitan Area Transit Authority (WMATA) as the technical reviewer who will operate the system. At the end of 2006, ownership of the project was transferred from DRPT to the Airports Authority. The Airports Authority engaged a Program Management Support Services (PMSS) consultant team that is led by Carter-Burgess.

In June of 2007 MWAA and DTP reached an agreement to build Phase 1 of the project that includes construction of the alignment to Wiehle Avenue near Reston in Northern Virginia. The Phase 1 segment is about 19 kilometers (11.6 miles) long and involves five stations of which two are at grade and three are elevated. Phase 1 is scheduled to be operational by 2013. The alignment of Phase 1 is generally at grade or elevated with the exception of a short underground section at Tysons Corner. The Tysons Corner alignment includes four Stations: Tysons East, Tysons 123 (at Route 123 near Tysons Galleria), Tysons Central 7 at State Route 7 and Tysons West within Route 7. The roughly 6 kilometers (20,000 feet) long Tysons Corner alignment with the four stations is shown in Figure 2. The short tunnels at Tysons Corner are located between Station 123 and Tysons Central 7. At the end of 2007 the DTP project team has developed plans for the early utility relocation package with utility relocation to begin early 2008. The design for the tunnel segment is expected to be issued for construction in 2008 and tunnel construction is scheduled to begin later in 2008.

SELECTION OF THE TYSONS CORNER TUNNEL

The preliminary engineering of Phase 1 essentially followed the general plans of the Locally Preferred Alternative (LPA) selected by WMATA and approved by other agencies out of many alternate alignments studied during the development of the LPA (DRPT, 2002). Among other options considered during the development of the Final Environmental Impact Statement (FTA, 2004) was an all tunnel alignment for Tysons Corner. This all tunnel option however was not selected mainly due to the high cost for tunneling that would have involved tunneling technologies for soft ground, mixed face, and hard rock conditions.

The LPA foresaw tunneling at a length of about 1.8 kilometers (6,000 feet) between the Tysons 123 Station in the east and to a point just west of the Tysons Central 7 Station. This alignment featured an all underground Central 7 Station constructed by cut-and-cover methods and is described in the LPA Tunnel Alignment section. The LPA as portrayed in the approved Final Environmental Impact Statement (FEIS) has practically been brought forward into preliminary engineering with a slight modification within the Tysons Corner Segment by placing the Metro alignment in the median of Route 7 and raising it to the surface at Tysons Central 7 Station location.

The alignment now features tunneling that as in the LPA will begin at an east portal near Tysons 123 Station and lead to Tysons Central 7 station to be built in a shallow cut but generally at grade (Figure 3). The tunneling is only about 730 meters (2,400 feet) long and involves cut-and-cover construction and the mined tunnel of about 520 meters

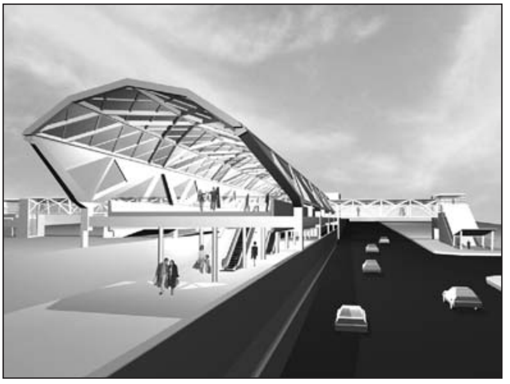


Figure 3. Tysons Central 7 station in Route 7 median looking east

(1,700 feet) constructed using NATM. This alignment was selected due to cost savings of some $200 million when compared to the LPA tunnels and underground station. The tunneling is described in the section on design-build tunnel alignment.

At the end of preliminary engineering of Phase 1 in late 2005 the project entertained an all tunnel option that would have been constructed using a large bore tunnel to accommodate all Tysons stations and track underground. The roughly 12.2 m (40 ft) diameter single bore tunnel length would have been about 6 kilometers (20,000 feet). Before that, DTP had independently studied a slightly shorter tunnel starting after the first station in Tysons, just before the rail crosses the Capital Beltway, to ensure all options had been fully explored. (Bonaiuto, 2005). Following intense studies of tunneling cost, schedule impacts and long-term benefits for the region, Virginia's Governor abandoned the large bore tunnel options in mid 2006. The reasons were mainly the high tunneling costs and possibility of loss of funding by the FTA due to significant project delays by some two to three years and the fact that it could have jeopardized the entire rail line (Mc Gillis, 2006.), described in the Large Bore Tunnel Option section.

LPA Tunnel Alignment

The Locally Preferred Alternative (LPA) is the "T6 alignment" as portrayed in the Final Environmental Impact Statement. According to this alignment, the running tunnels passed predominantly through residual soils and soil units consisting of alluvium and artificial fill. While at the portals tunneling would have been in soft alluvial soils in the mid section the tunnels would have been located within weathered bedrock at a depth of about 24 meters (80 feet). Most of the alignment was below the groundwater table. At the east section of the alignment the tunnels were to pass underneath International Drive, a busy, six-lane divided highway. It would have further passed underneath Route 123 and close by to an underground hotel-parking garage. At its west end it would have been located just south of Route 7.

Past WMATA tunneling experience (Rudolf et al., 2006) provided insight into feasible tunnel methods for the geologic conditions anticipated. Based on this local tunneling experience, and experience from similar underground transit projects, feasible tunnel construction methods included: (a) shielded TBMs, including open-face shields and pressure face machines, (b) the New Austrian Tunneling Method (NATM), and (c) cut-and-cover methods.

Due to the ground conditions some of these tunneling methods would have required the use of ground modification methods, predominantly dewatering, but possibly deep soil mixing, jet grouting, and/or permeation grouting with possible need for compensation grouting to limit settlements.

Four alternative construction approaches were developed for the underground structures during early stages of the preliminary engineering, excluding the Tysons Central 7 Station that was to be constructed in cut-and-cover methods using slurry wall for support of excavation and short cut-and-cover running tunnels at the ends of the alignment. The construction methods formally considered were as follows:

- Alternative 1: Combination Cut-and-Cover/TBM Concept
- Alternative 2: All NATM Concept
- Alternative 3: All TBM Concept
- Alternative 4: Combination NATM/TBM Concept

For each alternative, the running tunnels were divided into two reaches, which are summarized in Table 1.

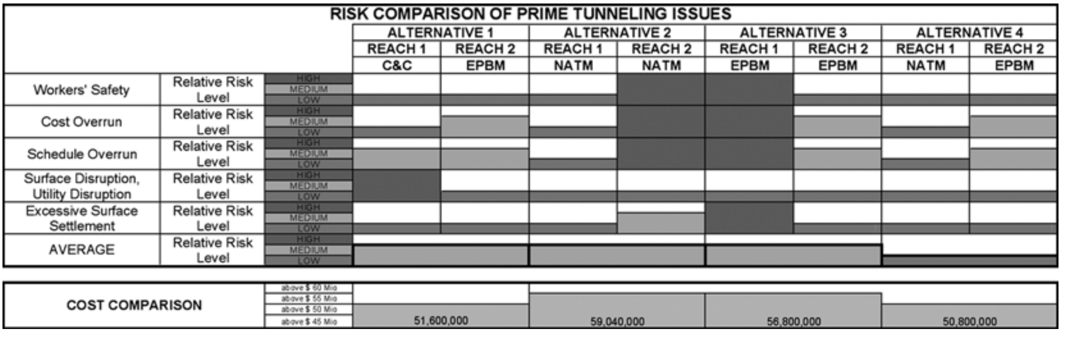
The tunnel construction methods were compared according to the following criteria:

- Potential for excessive surface settlements or heave,
- Tunneling safety,
- Potential for uncontrollable ground inflow,
- Adaptability to geologic uncertainty and buried obstructions,
- Severity of required surface disruption,
- Right-of-way and construction easement requirements, and
- Tunnel construction duration.

Table 1. Tunnel construction methods breakdown for each alternative and reach

Alternative	Reach 1 • Length=180 meters (600 feet) • Shallow Tunneling • Crown Generally Above Groundwater • Soft Ground	Reach 2 • Length=1,300 meters (4,300 feet) • Deep Tunneling • Crown Under Groundwater • Soft Ground, Mixed Face
1. Combination Cut-and-Cover / TBM	Cut-and-Cover	TBM
2. All NATM	NATM	NATM
3. All TBM	TBM	TBM
4. Combination NATM / TBM	NATM	TBM

Table 2. Tunneling methods risk and cost comparison matrix



Advantages of concepts including NATM in areas of adaptability and construction easement requirements were offset by construction duration advantages of mechanized (TBM) concepts. TBM concepts further had advantages over NATM concepts in controlling risks associated with ground inflows in areas of high hydraulic head. The cut-and-cover concepts had significant disadvantages of high surface disruption, construction easement requirements, and construction duration. To further investigate the tunnel construction methods a formalized risk combined with a cost analysis was undertaken to evaluate the methods considered. A summary table of the findings is presented in Table 2.

Based upon the evaluation of these tunnel construction methods and their impacts on the surrounding community, the Combined NATM / TBM Concept, Alternative 4, was recommended for further design development because it allowed mined tunneling methods earlier on in the construction phase with less surface disruption potential with smaller right-of-way and construction easement requirements. It further resulted in the least project risk and the most cost effective combination of tunneling concepts. According to Alternative 4 tunneling in Reach 2 was by closed face TBM methods using Earth Pressure Balance Machine (EPBM) and tunneling under the shallow overburden in particular underneath International Drive was according to the NATM. The NATM tunneling was laid out such as to create a tunnel to be used as a launch chamber for the TBM. The NATM soft ground tunnel concept is shown in Figure 4. EPBM tunneling was to use a one-pass lining, with gasket between pre-cast lining segments.

Following completion of this design to a 50% preliminary engineering (PE) level the project developed a cost estimate. As the overall project cost for Phase 1 was significantly higher than that included in the LPA a formal cost evaluation and value-engineering program was undertaken. This program resulted in the fact that major cost savings could be realized by building Tysons Central 7 Station as an at-grade structure rather than some 80 feet underground and by eliminating the tunnels west of that station. Due to the amount of cost savings of approximately $200 million based on this proposed change the at-grade Tysons Central 7 Station was adopted. This fact led to a modification of the tunnel alignment. The tunnel alignment was lifted significantly and such as to situate tunneling favorably with respect to the ground water elevation. A schematic comparison of the 50% PE alignment vs. the final PE alignment is shown in Figure 5. These changes led to shortening of the tunnels by over 50%. This alignment was brought to preliminary engineering and became the basis for the design-build contract and is described in the following section. The changes to the FEIS alignment were significant enough to require a supplemental Environmental Impact Statement, which was approved in mid 2006.

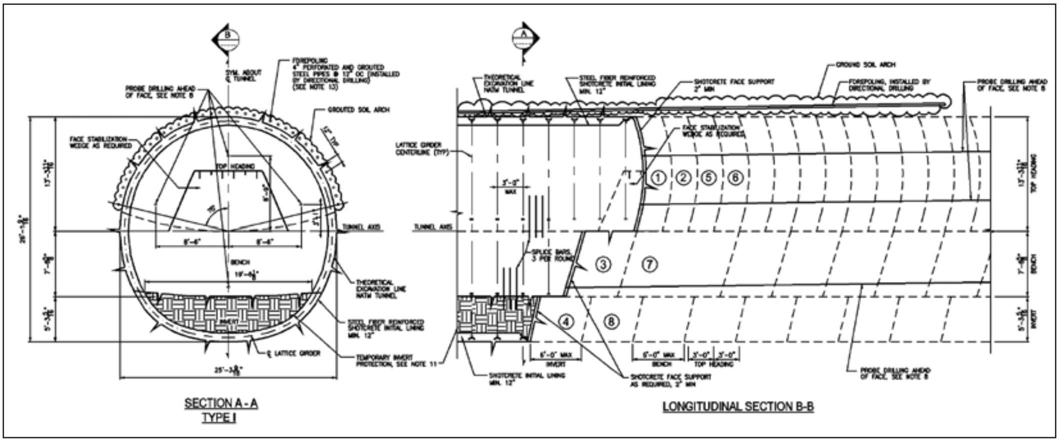


Figure 4. NATM for shallow tunneling and TBM launch

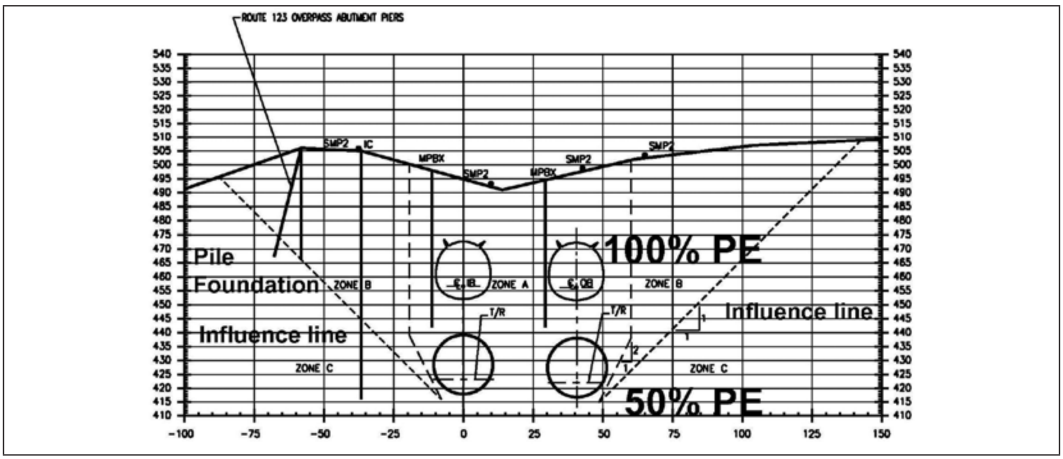


Figure 5. Deep tunnels of the FEIS alignment vs. shallow tunnels of the preliminary engineering

Design-Build Tunnel Alignment

The mined tunnel segment being advanced to final design includes twin single-track NATM tunnels at a length of approximately 520 meters (1,700 feet) each. A short cut-and-cover section adjoins the NATM tunnels at the east portal and a longer cut-and-cover section exists at the west portal. These tunnels will be constructed in soft ground and will be located adjacent to existing structures and utilities that are sensitive to ground movements. The alignment and elements of the short tunnels at Tysons Corner are shown in Figure 6.

The soils encountered along the tunnel alignment include mainly residual soils and soil like, completely decomposed rock. The residual soils are the result of in-place weathering of the underlying bedrock and are typically fine sandy silts and clays, and silty fine sands. According to project classification the residual soils are identified as Stratum S, which can be divided into two substrata based on the consistency and the degree of weathering. The upper substratum, S1, typically exhibits lower N-values (averaging 16 bpf or less) and has a higher fines content. Typical USCS classifications are ML, CL, and/or SM. Within the tunnel alignment, the thickness of substratum S1 varies considerably, from 0–0.6 meters to almost 10 meters (0–2 feet to almost 30 feet). The lower substratum, S2, is similar to S1, but typically exhibits higher N-values (averaging 16 bpf or greater) and is made up of more granular particles. Its thickness within the tunnel alignment ranges from 1.2 meters to 18 meters (4 feet to 60 feet). Substrata S1 and S2 will be the predominant soil types encountered during

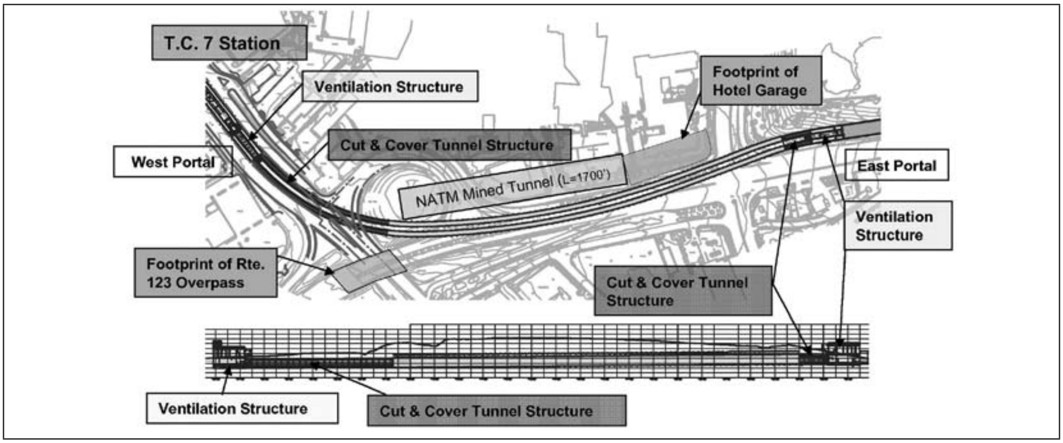


Figure 6. Design-build tunnel alignment

tunnel construction with tunneling within the S1 stratum mainly near the portals and stratum S2 where the tunnel is located deeper in the mid portion of the alignment. Only to a limited extent where the tunnel is deepest will tunneling encounter decomposed rock referred to as D1 in bench and invert. The decomposed rock is a soil like material but has higher blow counts with N-values between 60 bpf and 100 bpf. Ground water at portal locations is generally at invert elevation, in mid-point of the tunnel alignment it rises up to the tunnel spring line.

Prominent building and infrastructure elements located in the tunnel's vicinity include an underground parking garage at a distance of some 8 meters (25 feet) from the outbound tunnel wall and bridge piers of the Route 123/Route 7 overpass, at a clear distance of approximately 14 meters (45 feet) from the inbound tunnel, as well as International Drive, a six-lane divided highway located about 4.6 meters (15 feet) above the future tunnel crowns. Deepest overburden cover exists at about mid-point of the alignment with nearly 11.6 meters (38 feet). At the west portal and the transition to the cut-and-cover box the overburden is about 6 meters (20 feet). A section indicating geology, arrangement of the tunnels in the shallow location near International Boulevard and the parking garage is shown in Figure 7.

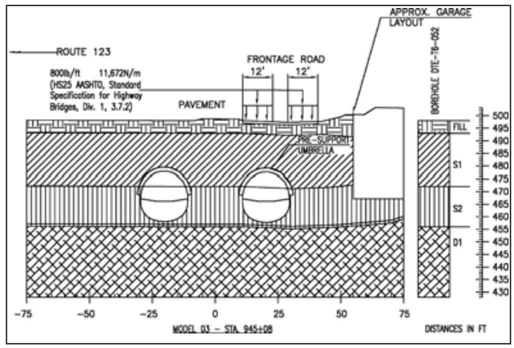


Figure 7. Arrangement of soft ground NATM tunnels near underground parking garage

Because of the shallow depth, the prevailing soft ground conditions, the relatively short tunnel length, and the need to control settlements the NATM has been chosen as the preferred tunneling method over open face shield options. To enhance stand-up time of the soils and minimize settlements a single row of a grouted pipe arch umbrella will be utilized for the entire length of the tunnels. This will be sufficient for pre-support where the overburden is greater and surface structures are less sensitive. An additional row of pipe arch umbrellas, using closely spaced approximately 114 mm (4.5 inch) diameter grouted steel pipes will be used on the first 90 meters (300 feet) length at the east portal where tunneling is shallow with some 4.6 meters (15 feet) or less of overburden. The pipes will be installed at 0.3 meter (one-foot) centers around the tunnel crown. Figure 8 displays the double row pipe arch umbrella above a typical single track NATM tunnel with shotcrete initial lining, closed PVC membrane waterproofing system and a cast-in-place concrete final lining.

The current tunnel alignment evolved through multiple cost, risk, and schedule considerations. The NATM tunnels initially continued for about another 120 meters (400 feet) to the west and under very shallow overburden of some 3 meters (10 feet) underneath Route 7 as compared to the alignment shown in Figure 6. Pre-support for this very shallow tunneling was foreseen to be by a double pipe arch canopy as shown in Figure 8. Risk concerns by the

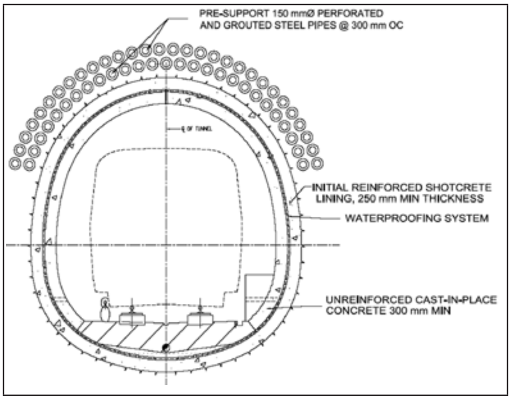


Figure 8. NATM tunnel with double pipe arch pre-support for shallow tunneling

pre-selected tunneling contractor however and the project insurer led to consideration of a top-down type pre-support installation for NATM tunneling. Figure 9 displays a schematic arrangement of a concrete slab constructed by cut-and-cover methods prior to tunneling. Installation for this slab however, posed traffic maintenance problems that were not satisfactory to the Virginia Department of Transportation (VDOT). This fact and tunneling cost considerations led to the implementation of two single track cut-and-cover tunnels that replaced the NATM tunneling at the western end of the tunnel alignment. An elaborate cut-and-cover construction sequencing and management of traffic (MOT) staging assuring three lanes of traffic to be maintained in each direction satisfied VDOT requirements. The transition from cut-and-cover tunneling to mined tunneling occurs at a depth where the overburden is about one tunnel diameter and mined tunneling is more economical that cut-and-cover construction.

Large Bore Tunnel Option for Tysons Corner

Late in the preliminary engineering of Phase 1 WMATA, in conjunction with a Spanish contractor and an Austrian design group strongly supported by a local developer, proposed an all-underground option for the roughly 6 kilometers (20,000 feet) long segment at Tysons Corner. The envisioned tunnel as proposed by the group would have been a large bore, 12.5 meters (41.5 foot) diameter driven tunnel to accommodate two over/under tracks and stacked station platforms inside the tunnel. It was based on a deep tunneling experience gained at the Barcelona Light Rail system (Della Valle, 2002 and 2005). Despite support of an underground option by many parties involved, its realization was found to cost from $250million to over $800 million more, based on various estimates than the mostly elevated and partially

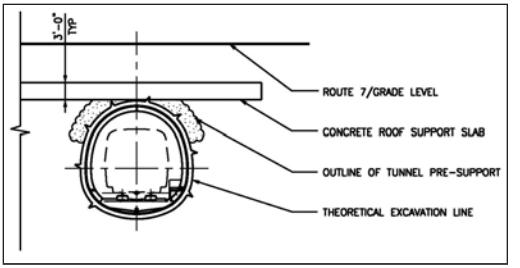


Figure 9. Alternative top-down slab tunnel pre-support

at-grade alignment including the short twin single track NATM soft ground tunnels. DRPT's cost estimate was at $500 million more than the LPA based design through Tysons Corner (MacGillis, April 2006). In reality, the large bore is four times larger in volume than one single-track tunnel and two times larger than two single-track Metro tunnels. There would be even a higher factor than two when comparing the concrete volume installed in the large bore vs. two single-track tunnels.

The large, 12.5 meters (41.5) foot diameter bore presents more risks in general, in particular when cutting 4.6 meters ± (15 feet ±) under an existing toll road bridge, and 3 meters ± (10 feet ±) under a culvert of the environmentally sensitive Scott Run than the excavation of two significantly smaller single bores, particularly when driven through mixed ground conditions with shallow soft ground cover. At several other locations such as the Interstate 495 Highway (Capital Beltway) and each toll road crossing including both portals the proposed alignment indicated less than one tunnel diameter of mainly weak soil or fill cover. With the large bore, extensive and deep excavations still would be needed for station entrances, ventilation fans, ancillary rooms, and ventilation / emergency egress shafts. The large tunnel bore scheme would have required handling of approximately 1.7 million cubic meters (2.2 million cubic yards) of excavated material not counting a swell factor. These facts indicated the trend towards much higher cost of the large bore tunnel, which would be difficult to compare with an aerial and at-grade alignment.

Furthermore the large diameter tunnel option proposed throughout the entire Tysons Corner segment would have significantly deviated from the NEPA selected and approved alignment as portrayed in the FEIS and the preliminary engineering documents. This new tunnel concept would have therefore involved another environmental approval process, and additional geotechnical studies to be followed by a new preliminary engineering. This in turn would have resulted in a project delay of some

2.5 to 3 years. The additional projected cost for the tunnel alternative would have practically led to the loss of funding by the Federal Transit Administration (FTA) and substantially delayed the project or possibly jeopardize the entire rail line. These factors and the fact that another up to three years would have postponed traffic congestion relief made the decision to move forward on the all-tunnel scheme very problematic. Supported by federal officials and local congressmen Virginia's Governor Timothy M. Kaine reaffirmed the Commonwealth's selection of the aerial alignment through Tysons. (MacGillis, Sept. 2006) and DTP resumed design work on the original Phase 1 project alignment.

However, regardless of this decision in November 2006 a local organization under the name of Tysons Tunnel, Inc. (TTI) with a major Tysons landowner and other supporters tried to revive the large bore tunnel and submitted an unsolicited large bore tunnel concept to DRPT for consideration in early 2007, hoping to reverse the decision against the tunnel (MacGillis, Nov. 2006). The claim had been made that this proposal was sufficiently developed and should be used similarly to the PE project design to invite a bid. This proposal was then subject to two independent engineering reviews. At the request of DRPT a review of the proposal and associated studies was carried out by a group of consultants headed by Carter-Burgess, Inc., who made the same conclusion as DRPT before that the tunnel would be too risky and expensive. It raised a long list of concerns including cost, timing, safety, and stated that the engineering study commissioned by tunnel supporters rested on questionable assumptions without sufficient geotechnical investigations at the tunnel depth.

The Washington Post and other local press reports noted that switching to the tunnel design could mean an additional two years for environmental and engineering studies and Federal reviews. They reported "The state study raised questions about the tunnel proposal, the four new Metro stations and pedestrian passageways tunneled at shallow depth under roadways, and that approximately 40% of the tunnel's alignment is less than one tunnel diameter below the surface increasing the possibility of cave-ins and sinkholes" (Turque and Sun, 2007).

At that time the FTA also initiated an independent review of the proposal and DRPT evaluation within the frame work of the Project Management Oversight Program (PMOC) by an engineering review group led by Hill International, Inc. who issued their report with detailed conclusions. They confirmed that the large bore tunnel would be more expensive and cause significant project delays and funding risk. The FTA-requested review report further stated that the large bore tunnel proposal was not biddable per FTA or industry standards and lacked a bottoms-up estimate to provide a confidence level into project cost. Other serious deficiencies identified between the two review reports included a longer construction schedule, the need for a new subsurface exploration program, the need for additional agency/owner/operator/local coordination that could cause major scope increases during final design and construction (FTA, May 2007).

Following FTA's assessment, WMATA initiated a peer review from the American Public Transportation Association (APTA) with the aim to compare the project DTP design and the proposed large bore tunnel with respect to long-term maintenance and operation cost and "non-quantifiable" items. The APTA review concluded that although rehabilitation cost for the tunnel might be lower the net savings for the tunnel over 30 years would be about $60 million and with respect to overall budget cost were not significant for the purpose of option evaluation (APTA, 2007).

Many residents in the area would like to have a tunnel through Tysons Corner, but recognizing reality and desire to have the Metro connection to Tysons Corner and to Dulles International Airport in Northern Virginia, they support the approved LPA alignment and the Dulles Corridor Metrorail Project (DCMP) project as designed. Those who were familiar with the project development history are aware that there was a long waiting period since the Major Investment Study started in 1996 and the long process of environmental reviews, Record of Decision, Preliminary Engineering, and Firm Fixed Price negotiations process and have stated firmly that now it's time to complete final design and start construction of the Phase 1 DCMP project to Dulles Airport. (Wright D., May 2007; Nicoson P., May 2007). Most State and local leaders, and communities support the plan and contract which move the project forward as planned and approved (Stower J., March 2007).

The Fairfax County Board of Supervisors after many meetings overwhelmingly voted for the LPA alignment and committed to funding their portions of the Metrorail extension to Dulles International Airport and beyond, fully realizing that further push for the big bore would jeopardize, possibly forever, the entire Metrorail link to the Airport. Loudoun County also voted and committed funding for extension with the present alignment through Tysons Corner. "The Fairfax vote was the right one for Tysons. Elevated or underground, the Dulles extension will bring enormous benefits to the region (second downtown) in the form of added foot traffic, efficiency and convenience" writes Washington Post Editorials (WashingtonPost.com, June 2007).

"We had an obligation to look thoroughly at the tunnel option," said Connolly, the Chairman of Fairfax County Board of Supervisors, who ultimately supported the aerial alignment to save the project.

The tunnel is "clearly the preferable way to go if it's feasible. But at the end of the day, it was determined not to be feasible" (Turque B. August 2007).

FTA officials say the tunnel discussion set the project back as much as a year. During that time, dramatic inflation among such commodities as steel and asphalt accounted for much of the cost increases (Gardner A., August 2007).

The Dulles Corridor Rail Association, an advocacy group for the rail extension, recently contracted for a survey, which found that 87 percent of residents in the Greater Washington area favor the project (Times Community Newspapers, October 10, 2007).

A consortium of 20 Tysons Corner property owners along the route of the long-sought extension of Metrorail to Dulles International Airport have created a coalition to launch a public campaign to secure federal funding for the project and increase development in the area. The business coalition is also seeking to end the pressure from tunnel advocates because they fear the push could cause further delays and scuttle the project. Plans now call for an aerial track, and the effort to alter that plan has been blamed for jeopardizing approval of the 23-mile line (Gardner, A. December 2, 2007 *Washington Post*).

Tysons Corner property owners are coming together to make sure the planned extension of Metrorail to Dulles Airport becomes a reality. The coalition, called Tysons Tomorrow, is launching a public campaign to secure federal funding for the project and increase development in the area (*ABC 7 News*, December 2, 2007).

IMPLEMENTATION

Public Private Partnership (PPP)

The project is being implemented in a Public-Private-Partnership under the Public Private Transportation Act (PPTA) an innovative project delivery framework as established by the Virginia Department of Transportation (VDOT) in 1995. Its implementation is in accordance with the guidelines as amended by the General Assembly in 2005 (The Commonwealth of Virginia, 2005), and the process has been found by FTA to meet federal requirements for competition. The essential goals of the PPTA are to encourage investment in the Commonwealth by creating a more stable investment climate and increasing transparency in a competitive environment and public involvement in the procurement process. According to the guidelines the private entity charged with project implementation is required to provide certain commitments or guarantees and enters into a negotiated risk sharing. Development of the Dulles Corridor Rapid Transit Project is an example of a PPP, where a private consortium facilitates public financing for the project and provides its full development in exchange for a negotiated Design-Build contract of the facilities. Per the terms and conditions of the comprehensive agreement, a firm fixed price (FFP) for construction is submitted to the client. This FFP is a detailed (bottom-up contractor's estimate) Design-Build proposal, which is then negotiated on an open book basis before Final Design and Construction starts (Martinez, 2006).

Design and Construction

The project is being realized under a design-build contract. The design-builder, Dulles Transit Partners was required to initially develop preliminary engineering for the rail project. The cost for the preliminary engineering was shared between the design-builder and the project partners, DRPT, FTA, MWAA and the counties of Fairfax and Loudoun. The preliminary engineering formed the basis for the fixed firm price contract. To maintain previously established budget limits this results in design challenges and the need to optimize design and construction methods to build to budget. Consequently, many design iterations were required during preliminary engineering as was demonstrated in the genesis of the tunnel arrangement from an initial LPA alignment through its variations to the short mined NATM tunnels with an at-grade Tysons Central Station. During the final design the design and construction team will further weigh the benefits of underground tunneling adaptations. Value Engineering (VE) is a central activity of the design-build contract in pursuit of the most economical approach in particular in view of the ever-increasing cost of nowadays heavy construction market.

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