4.0 - ENGINEERING ISSUES REPORT
Sepulveda Pass Corridor Systems Planning Study

Engineering Issues Report

Prepared for:

Metro

Prepared by:

HNTB Corporation

in collaboration with Parsons Brinckerhoff, EMI, IBI Group, and V&A

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1 INTRODUCTION
This report presents refined corridor system concepts, rough-order-of-magnitude cost estimates, key engineering elements for each concept and issues needing further study. The concepts have been developed through working sessions with Metro planning staff, input from the other consultant teams working on the Transportation Planning, Demand Modeling, and Environmental task orders for the Sepulveda Pass Corridor Systems Planning Study, and from input received at Planning Charrette 1 and 2.

This report provides a summary description of the concepts and any changes resulting from Charrette 2, high-level, conceptual cost estimates, information on key design elements, geotechnical assessments, constructability issues, and issues uncovered during the course of this study that need further investigation and analysis. In addition, conceptual drawings for the concepts are included in the Appendix.

2 CORRIDOR SYSTEM CONCEPTS
The six concepts are presented in further detail in the following sections. In general, Concepts 1 and 2 are mainly at-grade or surface alternatives, Concept 3 is an aerial viaduct alternative, and Concepts 4 through 6 incorporate major subsurface (tunnel) components.

2.1 At-Grade Van Nuys/Septulveda Boulevard Bus Rapid Transit (BRT)
The proposed at-grade BRT provides a connection between Century Boulevard station with the Green Line and Crenshaw/LAX Light Rail Transit (LRT) line on the south to the San Fernando MetroLink Station to the north. Intermediate stops are proposed at Nordhoff Street, Van Nuys MetroLink/Amtrak, Orange Line Sepulveda Station, Wilshire Boulevard (Westside Subway), Exposition LRT, and Jefferson Boulevard.

The at-grade BRT service traveling along existing roadways will be enhanced by the provision of Bus on Shoulder operations across Sepulveda Pass on I-405 (in both directions), and the provision of traffic signal priority, and queue jump lanes at selected intersections along Sepulveda Boulevard, Van Nuys Boulevard, and San Fernando Road. These enhancements are described below.
Figure 1. Concept 1 At-Grade Van Nuys/Sepulveda BRT Map
2.1.1 Key Engineering Elements

2.1.1.1 Concept Design Elements
The primary engineering design elements associated with Concept 1 are traffic signal and intersection striping modifications associated with queue jump improvements for the proposed BRT service and signing and striping associated with the bus on should operations on I-405 (the north side of the Sepulveda Pass). This concept also assumes the reconfiguration of the Orange Line Sepulveda station.

2.1.1.2 Geotechnical Assessment
No uncommon geotechnical issues are anticipated for the roadway facilities required for Concept 1.

2.1.1.3 Constructability Issues
No negative constructability issues are anticipated for Concept 1, on the contrary, Concept 1 may present improved constructability due to its limited construction needs, lower cost and ability to phase intersection and vehicle improvements associated with queue jumps and transit signal priority.

2.1.2 Rough-Order-of-Magnitude Costs
The majority of the unit cost factors used to develop the rough-order-of-magnitude cost estimates were provided by the Metro Cost Estimating Departments. There were certain cases where unit costs were not provided by Metro and the design team relied up available data from similar projects and industry resources, which were reviewed and approved for use by Metro personnel.

The unit costs used for this study represent the concepts at a very high level; alternatives are quantified by a cost per mile unit and major features such as transit stations are assigned a typical unit factor. Where appropriate, the unit costs have been adjusted to reflect economies of scale. The cost estimates have also been adjusted to reflect the physical characteristics of the concept. For example, the typical Metro rail project has a station every mile, whereas some concepts were envisioned to have fewer stations per mile and the unit costs were adjusted accordingly. Lastly, unit costs were developed to reflect program costs and a 30 percent contingency was applied to each concept’s total applied unit cost in order to account for the preliminary nature of this feasibility level assessment.

See the Sepulveda Pass Corridor Systems Planning Study Preliminary Cost Report for a full discussion on the costing methodology, unit cost values, general assumptions, and concept specific assumptions and adjustments applied to develop the rough-order-of-magnitude cost estimates.
2.1.2.1 Capital Cost Estimate

The major components of the concept used to develop the rough-order-of-magnitude cost estimate are:

- Shoulder improvements on the northbound and southbound I-405 to accommodate shoulder running buses from Ventura Boulevard to Sepulveda Boulevard
- At-grade BRT Station
- Modifications at the Orange Line station
- Priority treatments, intersections modifications, and queue jump lanes along Sepulveda Boulevard and Van Nuys Boulevard

The rough-order-of-magnitude capital cost estimate for Concept 1 is anticipated to be $162M.

2.1.2.2 Vehicle Cost Estimate

Vehicle costs associated with Concept 1 include vehicles for the proposed Bus Rapid Transit service. A planning-level calculation for both a low and high range fleet size was performed as part of the Demand Modeling task order. The low and high range fleet sizes reflect the provision of BRT service across the Sepulveda Pass. The second component associated with the vehicle cost estimates, is fleet type. Two different fleet options reflect the need for BRT service to maintain a 45 mph speed in the managed lane facility across Sepulveda Pass. The first fleet option replaces the engine and transmission of existing vehicles in Metro’s fleet with a more powerful engine and transmission that can maintain 45 mph and the other is for the purchase of new vehicles (differing from current fleet) that can maintain 45mph across the Sepulveda Pass.

Based on the above consideration, vehicle costs for Concept 1 range from $2M to $37M (refurbished compared to new vehicle purchase) for the estimated low range of BRT service, and from $4M to $78M for the high range of BRT service, for refurbished and new vehicles respectively.

2.1.2.3 Operations and Maintenance Cost Estimate

Operating and maintenance cost estimates were developed using the operating and maintenance cost figures as reported in the Metro Proposed Budget for Fiscal Year 2013, and average weekday passenger mile results from the demand modeling efforts. Based on these inputs, average annual operating costs for BRT operations included as part of Concept 1, the at-grade Sepulveda Boulevard BRT, were estimated at $96M per year.
2.1.3 Issues for Further Investigation and Analysis

Further inquiries and investigation with Caltrans and other municipal agencies that maintain and operate the roadway facilities proposed for the new BRT service will need to be undertaken to understand each agency’s particular requirements for implementing bus on shoulder operations and intersection signal, signing and striping changes for queue jump and transit signal priority measures.

2.2 At-Grade Freeway Managed Lanes

Concept 2 would implement managed lane operations in the center lanes of I-405 from the I-5 interchange in the north to the I-105 interchange in the south. Between US-101 and La Grange Avenue, I-405 is proposed to consist of five general purpose (GP) lanes and two managed, high occupancy toll (HOT) lanes in each direction. A possible exception to the provision of five general purpose lanes would be to maintain the four lane section in the southbound direction to limit freeway widening. North of US-101 and south of Santa Monica Boulevard, there would only be one managed HOT lane in each direction.

At the point where the managed lanes transition from two lanes to one lane (at US-101 and at La Grange Avenue), one of the managed lanes will be dropped or added (depending on the direction of travel) to a connecting roadway using direct access ramps. At the north end, a direct access ramp connection to US-101 would provide a connection from the I-405 managed lanes to US-101 serving traffic with origins or destinations west of I-405 (no connections provided for areas east of I-405). As such, traffic going northbound on I-405 would be able to go westbound on US-101 or continue northbound on I-405 depending on lane selection and traffic eastbound on US-101 would have the option of directly entering the I-405 southbound managed lanes via a direct access ramp connection.

The southern Direct Access Ramp connection is proposed to be constructed at La Grange Avenue, just south of Santa Monica Boulevard. In this scenario, ramps would connect the managed lanes in the median of I-405 with a structure to La Grange Avenue (connection could either be under or over I-405). Ramps on the outside of each side of the freeway would provide a connection for managed lanes traffic to the adjacent local streets. As designed, the adjacent local streets (Beloit Avenue on the west side of I-405 and Cotner Avenue on the east side of I-405) would be converted to one way streets, but kept at their existing elevation to maintain access to adjacent properties (other design options may allow for two-way traffic on the frontage roads).

BRT vehicles utilizing the I-405 managed lanes are proposed access to the Orange Line Busway via direct access ramps. The proposed design would allow buses to travel under the northbound lanes of I-405 using a new undercrossing and then access the managed lanes on I-405 via center lane on and off ramps. Standard in-lane ingress and egress from the general purpose lanes to the managed lanes could also be provided at standard Caltrans intervals. Similarly, additional
access to the managed lanes (north and south of the two-lane Sepulveda Pass section) could also be provided via additional direct access ramps.

Figure 2. Concept 2 At-Grade Freeway Managed Lanes
2.2.1 Key Engineering Elements

2.2.1.1 Concept Design Elements
The primary design elements for this concept include the implementation of managed lane operations from approximately the I-5 in the north to the I-105 in the south. The majority of the distance between I-5 and I-105 would be a single lane conversion of the existing HOV lane, with a core segment of two-lane operation (in each direction) across the Sepulveda Pass from the US-101 to La Grange Avenue.

The single lane sections require signing and striping changes, as well as the installation of tolling equipment for managed lane operations. Design elements required for the construction of the two-lane segment of the managed lanes concept would require construction of direct access ramps to connect to the Orange Line, US-101 to and from the west, and at La Grange Avenue, as well as the signing, striping and tolling elements associated with the single lane operations. Construction of the direct access ramp will require additional right-of-way for two of the three proposed locations. At the Orange Line, additional right of way will be required to shift the northbound mainline I-405 lanes to the west, and additional right-of-way will be required to widen I-405 where the direct access ramps from the US-101 will join the two-lane section of managed lanes crossing Sepulveda Pass. The proposed direct access ramps at La Grange Avenue are anticipated to remain within the existing I-405 right-of-way envelope.

2.2.1.2 Geotechnical Assessment
No uncommon geotechnical issues are anticipated for the roadway facilities required for Concept 2.

2.2.1.3 Constructability Issues
Construction of the direct access ramp structures and any associated I-405 freeway mainline construction required to accommodate the direct access facilities is expected to impact traffic operations on I-405 and all adjacent and intersecting roadway facilities. Considerable traffic control and mitigation measures are expected to be required during construction activities.

2.2.2 Rough-Order-of-Magnitude Costs
See Section 2.1.3 of this report for a brief discussion of the methodology and assumptions used when developing the rough-order-of-magnitude costs or the Sepulveda Pass Corridor Systems Planning Study Preliminary Cost Report for a more in-depth discussion.
2.2.2.1 **Capital Cost Estimate**

The major components of the concept used to develop the rough-order-of-magnitude cost estimate are:

- Direct Access Ramps at the Orange Line Busway, US-101, and La Grange Avenue
- Construction of express lanes which would include restriping, physical barriers, and tolling equipment;
- The incorporation of the BRT improvements from Concept 1 for areas outside of the Sepulveda Pass (Van Nuys and Sepulveda Boulevard).

The rough-order-of-magnitude capital cost estimate for Concept 2 is anticipated to be $1.6B with $0.5B being attributed to the transit-only components of the concept and $1.1B attributed to the highway based components.

2.2.2.2 **Vehicle Cost Estimate**

Vehicle costs associated with Concept 2 are the same as for Concept 1, as the proposed BRT service is the same for both concepts. As noted for Concept 1, vehicle costs for the lower range of BRT service across Sepulveda Pass is estimated from $2M to $37M (refurbished and new vehicles respectively) and from $4M to $78M for the high range of BRT service, again for refurbished and new vehicles respectively.

2.2.2.3 **Operation and Maintenance Cost Estimate**

Operating and maintenance cost estimates were developed using the operating and maintenance cost from the Metro Proposed Budget for Fiscal Year 2013 and average weekday passenger miles results from the demand modeling efforts for the Sepulveda Pass Corridor Systems Planning Study. Based on these inputs, average annual operating costs for BRT operations included as part of Concept 2, the at-grade freeway managed lanes, were estimated $138M per year.

2.2.3 **Issues for Further Investigation and Analysis**

Further traffic analysis is needed to better understand expected managed lane operations, particularly at the two to one lane transition points at US-101 and La Grange Avenue, as well as for the single lane sections to the north of US-101 and south of La Grange Avenue.
2.3 Aerial Viaduct Managed Lanes

The highway viaduct proposed for Concept 3 is an elevated guideway above the median of the I-405 between the US-101 to the I-10. The conceptual aerial viaduct structure would consist of four managed lanes (two in each direction) and would be constructed in the median/shoulder area of the I-405 freeway. As designed, the structure would be supported by 10 foot wide center running columns, utilizing 5 feet of inside shoulder from the exiting north and south bound directions.

Access to the highway viaduct is proposed in three locations, north of US-101 at Burbank Boulevard, at US-101 and a southern access point at La Grange Avenue. The elevated structure would begin at Burbank Boulevard where it would connect to the existing overcrossing, pass over US-101 with direct access ramp connections to US-101 for travelers with origins or destinations west of I-405, travel across the pass and south to the proposed terminus at La Grange Avenue where an aerial T-ramp would provide connections to local streets via La Grange Avenue.
Figure 3. Concept 3 Aerial Viaduct Managed Lanes
2.3.1 Key Engineering Elements

2.3.1.1 Concept Design Elements
The primary design elements for this concept is the aerial viaduct structure and associated direct access structures and ramps at Burbank Boulevard, US-101 and La Grange Avenue. Construction of the proposed direct access locations, as currently designed, are anticipated to require additional right-of-way.

2.3.1.2 Geotechnical Assessment
While no uncommon geotechnical issues are anticipated for the roadway facilities required for Concept 3, geologic and seismic issues should be analyzed in depth to accurately portray any geotechnical or seismic issues associated with an elevated structure of this size.

2.3.1.3 Constructability Issues
Construction of the aerial viaduct and associated direct access ramp structures is expected to impact traffic operations on I-405 and all connecting roadway facilities. Considerable traffic control and mitigation measures are expected to be required during construction activities.

2.3.2 Rough-Order-of-Magnitude Costs
See Section 2.1.3 of this report for a brief discussion of the methodology and assumptions used when developing the rough-order-of-magnitude costs or the Sepulveda Pass Corridor Systems Planning Study Preliminary Cost Report for a more in-depth discussion.

2.3.2.1 Capital Cost Estimate
The major components of the concept used to develop the rough-order-of-magnitude cost estimate were:

- Construction of a four-lane elevated guideway between Burbank Avenue and La Grange Avenue;
- Direct Access Ramps at Burbank Avenue, US-101 and La Grange Avenue; and
- The incorporation of the BRT improvements from Concept 1 for areas outside of the elevated viaduct structure (Van Nuys and Sepulveda Boulevard).

The rough-order-of-magnitude capital cost estimate for Concept 3 is anticipated to be $2.3B with $0.13B being attributed to the transit-only components of the concept and $2.2B attributed to the highway based components.
2.3.2.2 Vehicle Cost Estimate
Vehicle costs associated with Concept 3 are the same as for Concept 1, 2, and 4 as the proposed BRT service is the same for all concepts. As noted for Concept 1 and 2, vehicle costs for the lower range of BRT service across Sepulveda Pass is estimated from $2M to $37M (refurbished and new vehicles respectively) and from $4M to $78M for the high range of BRT service, again for refurbished and new vehicles respectively.

2.3.2.3 Operation and Maintenance Cost Estimate
Operating and maintenance cost estimates were not calculated for Concept 3, as transportation demand modeling efforts were not undertaken for this Concept.

2.3.3 Issues for Further Investigation and Analysis
If Concept 3 is progressed, community based impacts would need to be analyzed and assess. An aerial viaduct is anticipated to create visual quality impacts to residents and businesses adjacent to the I-405 freeway and community impacts during construction may prove to be particularly challenging coming on the heels of the current construction of the I-405 Sepulveda Pass Widening Project.

Additional engineering issues for further analysis and investigation include analyzing the feasibility of using a single column structural approach for the aerial viaduct structure, and ability to provide the needed clearances from existing structures within the US-101 interchange to provide the connector from northbound I-405 to eastbound US-101.

Further traffic analyses needs to be performed to determine the traffic demand and capacity required at the proposed access and egress locations to the elevated viaduct to better understand the operational feasibility of the concept. Traffic management may be somewhat more challenging for Concept 3 than for Concept 2, due to the limited entry and exit points to the viaduct facility, as compared to the potential for intermediate entry and exit points that could be provided from the adjacent general purpose lanes under Concept 2.

Lastly, a highway viaduct concept was considered in the EIR for the I-405 Sepulveda Pass Widening Project, and was ultimately withdrawn due to seismic safety concerns. While a seismic assessment of individual concepts was not completed as part of this study, it would be expected that any further study on this concept would result in similar conclusions regarding seismic issues.
2.4 Tolled Highway Tunnel

Concept 4 would construct a bored tunnel under the Santa Monica Mountains that would carry two lanes of highway traffic in each direction. The tolled tunnel concept is anticipated to have a cross section consisting of either a single bore with two lanes on an upper level and two lanes on a lower level, or two separate bores with two lanes in each bore. Traffic in the tunnel would include both autos and buses. A graphic depicting Concept 4 is shown on the following page.

The tunnel alignment would begin near the I-405/US-101 interchange and would extend south through the Santa Monica Mountains, then south-southeast through Century City east of and loosely following the I-405 roadway (approximately 9 miles). Similar to Concept 2, the southern terminus of the tunnel would be located near La Grange Avenue.
Figure 4. Concept 4 Tolled Highway Tunnel
2.4.1 Key Engineering Elements

2.4.1.1 Concept Design Elements
The primary design elements for Concept 4 are the tunnel structure and the tunnel portal structures near US-101 and La Grange Avenue. Two tunnel portals are needed at the US-101 interchange, one for traffic coming to and from I-405 to the north and one for traffic coming from US-101 to the west. Two concepts were developed for the US-101 tunnel portal connections, the first connects I-405 and US-101 with the tunnel portals with flyover ramps (direct access ramps) to a single, large bore tunnel, and the second would be independent tunnels to I-405 and US-101 that would later join into a single tunnel.

![Diagram of tunnel structure](image)

**Figure 5.** Typical cross-section: Single bore tunnel (stacked roadway) alternative with vertical egress points.
2.4.1.2 Geotechnical Assessment

Site specific geological and environmental considerations such as locations and orientation of major seismic faults, historical oil fields, favorable geological formations, widely varying ground water in the study corridor levels regime are of great importance while establishing a desired alignment profile for the selected route.

The alignment is located in a seismically active region and there are numerous potentially active faults in the area. Two of these faults had major earthquakes – North Northridge Hill in 1994 and San Fernando in 1971. Therefore seismic hazards such as fault rupture, seismic shaking, liquefaction and landslides need to be evaluated. Seismic slope stability at portals as well as liquefaction potential of portal structures will require further evaluation. Potential displacements along the existing faults need to be evaluated during design.

In addition to seismic hazards, other geologic hazards that exist in the project area include oil field related hazards, expansive and collapsible soils, and landslides/rock topple (which could impact portals and to a lesser extent, ventilation shafts). The tunnel design must consider the geohazards described above. For example, tunnel joints must be designed to accommodate the anticipated seismic movements, especially where the tunnel connects to portals, shafts and cross passages. In extreme cases (e.g., if the tunnel crosses a fault that has potential for an abrupt displacement), an oversized structure may be considered to accommodate the movement.

Additional information regarding geotechnical issues can be found in the Geotechnical Evaluation Memorandum (Metro, June 20, 2012).
2.4.1.3 Constructability Issues
Constructability issues associated with Concept 4 are mainly surrounding the launch and retrieval of the tunnel boring machine, the launch, retrieval and use of a tunnel boring machine for a single, large-bore tunnel. Further detail on these and other constructability issues include, but are not limited to the following items:

- Siting acceptable portal locations at each end of the tunnel to provide sufficient staging areas required to launch and retrieve the tunnel boring machine.
- The need to separate traffic in the northbound tunnel into two directions, northbound I-405 and westbound US-101, which is expected to require construction of diverging cut-and-cover portal boxed sections that will interface the bored tunnel.
- The southern tunnel portal connections at La Grange may require shifting of the I-405 freeway mainline lanes to create sufficient space in the median for a tunnel portal.
- The removal, transport and identification of locations in which to deposit the excavated soil resulting from the bored tunnel construction, which is estimated at approximately 7.6 million cubic yards.
- Siting of ventilation plants and associated appurtenant tunnel structures within a densely developed urban environment.

2.4.2 Rough-Order-of-Magnitude Costs
See Section 2.1.3 of this report for a brief discussion of the methodology and assumptions used when developing the rough-order-of-magnitude costs or the Sepulveda Pass Corridor Systems Planning Study Preliminary Cost Report for a more in-depth discussion.

2.4.2.1 Capital Cost Estimate
The major components of the concept used to develop the rough-order-of-magnitude cost estimate are:

- A large diameter bore tunnel; and
- Tunnel portals and approaches on either end of the tunnel.

A low range and high range estimate were developed for the tunnel portions of the alignment, with the low range cost representing a 20 percent reduction to reflect an assumed economy of scale associated a tunnel of this length (as compared to a 1 to 2 mile tunnel from which the costs were based). The rough-order-of-magnitude capital cost estimate for Concept 4 ranged from a low range of $10.4B to a high estimate of $12.9B.

2.4.2.2 Vehicle Cost Estimate
Vehicle costs associated with Concept 4 are the same as for Concept 1 and 2, as the proposed BRT service is the same for all concepts. As noted for Concept 1 and 2, vehicle
costs for the lower range of BRT service across Sepulveda Pass is estimated from $2M to $37M (refurbished and new vehicles respectively) and from $4M to $78M for the high range of BRT service, again for refurbished and new vehicles respectively.

2.4.2.3 Operation and Maintenance Cost Estimate
Operating and maintenance cost estimates were developed using the operating and maintenance costs reported in the Metro Proposed Budget for Fiscal Year 2013 and average weekday passenger miles results from the demand modeling efforts for the Sepulveda Pass Corridor Systems Planning Study. Based on these inputs, average annual operating costs for BRT operations included as part of Concept 4, the tolled highway tunnel, were estimated $127M per year.

2.4.3 Issues for Further Investigation and Analysis
Further analysis is needed regarding possible portal configurations in order to examine favorable construction staging schemes that would minimize right-of-way requirements and reduce traffic impacts and lane closures.

Tunnel and tunnel portal construction near existing structures will require additional analyses to determine to minimize the impacts to foundations of the existing structures that are adjacent to the tunnel and tunnel portals.

In addition, as noted for Concept 3, traffic management is somewhat more challenging for Concept 4 than for Concept 2, due to the limited entry and exit points to the tunnel facilities. As noted for Concepts 2 and 3, further traffic analyses needs to be performed to determine the traffic demand and capacity required at the proposed portal locations to better assess (tunnel and local street) operational feasibility of the concept and the access and egress locations.
2.5 Fixed-Guideway Light Rail or Heavy Rail Tunnel

Concept 5 proposes a rail line connecting the San Fernando Valley with the West Los Angeles and the Los Angeles Airport. The line would extend approximately 28 miles and connect the Sylmar/San Fernando Metrolink station in the north to the Century Aviation Station to the south. Fifteen stations are proposed with station spacing that is generally 2 miles apart.

Starting at the Sylmar Metrolink station, the rail alignment would run parallel to the existing Antelope Valley tracks before turning south onto Van Nuys Boulevard and traveling south to Ventura Boulevard where it would enter a tunnel portal and travel underneath the Santa Monica Mountains to a portal location south of Santa Monica Boulevard. The rail line would travel south on Westwood Boulevard to Overland Avenue. From Overland Avenue, the line would continue south to Sepulveda Boulevard where it would connect to the Metro Crenshaw or Green Line at the Century Aviation Station.

There are two options associated with this concept, Concept 5A is a light rail alignment that would run at grade in the San Fernando Valley, travel in a tunnel configuration under the Santa Monica Mountains, and then run in an at-grade configuration through West Los Angeles to the Century Aviation Station near LAX. Concept 5B is a heavy rail alignment that has been assumed to run entirely in a tunnel configuration, following the same alignment.
Figure 7. Concept 5 Fixed Guideway Light Rail or Heavy Rail Tunnel
2.5.1 Key Engineering Elements

2.5.1.1 Concept Design Elements
The major design components associated with Concept 5A include at-grade light rail track and necessary associated facilities systems and at-grade stations. Concept 5B includes dual bore tunnels and necessary associated facilities and systems and underground station. Both Concept 5A and Concept 5B have also assumed the need for a maintenance facility.

2.5.1.2 Geotechnical Assessment
As discussed for Concept 4, site specific geological and environmental considerations such as locations and orientation of major seismic faults, historical oil fields, favorable geological formations, widely varying ground water in the study corridor levels regime are necessary to consider when establishing a desired alignment profile for the selected route.

The alignment is located in a seismically active region and there are numerous potentially active faults in the area. Two of these faults had major earthquakes – North Northridge Hill in 1994 and San Fernando in 1971. Therefore seismic hazards such as fault rupture, seismic shaking, liquefaction and landslides need to be evaluated. Seismic slope stability at portals as well as liquefaction potential of portal structures will require further evaluation. Potential displacements along the existing faults need to be evaluated during the design of the tunnel.

In addition to seismic hazards, other geologic hazards that exist in the project area include oil field related hazards, expansive and collapsible soils, and landslides/rock topple (which could impact portals and to a lesser extent, ventilation shafts). The tunnel design must consider the geohazards described above; for example tunnel joints must be designed to accommodate the anticipated seismic movements, especially where the tunnel connects to portals, shafts and cross passages. In extreme cases (e.g., if the tunnel crosses a fault that has potential for an abrupt displacement), an oversized structure may be considered to accommodate the movement.

Additional information regarding geotechnical issues can be found in the Geotechnical Evaluation Memorandum (Metro, June 20, 2012).

2.5.1.3 Constructability Issues
The constructability issues associated with Concept 5 are very similar to those discussed for Concept 4, with the exception of the freeway connections. However, this concept would require the siting of a new maintenance and yard shop facility.
It should also be noted that Metro has extensive experience with the design and construction of LRT facilities, including 20 foot diameter transit rail tunnels, which mitigates some of the identified risks associated with Concept 4.

2.5.2 Rough-Order-of-Magnitude Costs
See Section 2.1.3 of this report for a brief discussion of the methodology and assumptions used when developing the rough-order-of-magnitude costs or the Sepulveda Pass Corridor Systems Planning Study Preliminary Cost Report for a more in-depth discussion.

2.5.2.1 Capital Cost Estimate
Based on direction from Charrette 2, cost estimates were developed for a light rail concept option and a heavy rail concept option. The light rail option would operate in an at-grade configuration on either side of the tunnel from Ventura Boulevard to approximately Santa Monica Boulevard. The “heavy rail” concept option (5B) is assumed to operate in a tunnel configuration for the entire length. Both the light rail and the heavy rail concept options include 14 stations. The major components of the concept used to develop the rough-order-of-magnitude cost estimate are:

- At-grade light rail
- At-grade transit stations
- Dual bore tunnels
- Underground transit stations
- A maintenance facility

A low range and high range estimate were developed for the tunnel portions of the alignment, with the low range cost representing a 20 percent reduction to reflect an assumed economy of scale associated a tunnel of this length. The rough-order-of-magnitude capital cost estimate for Concept 5 ranged from a low range of $7.4B to $8.3B for the light rail concept option to a high estimate of $13.6B to $17.5B for the “heavy rail” concept option.

2.5.2.2 Vehicle Cost Estimate
Vehicle cost associated with the proposed rail service for Concept 5, are included in the overall per mile capital costs discussed above.

2.5.2.3 Operation and Maintenance Cost Estimate
Operating and maintenance cost estimates were developed using the operating and maintenance costs as reported in the Metro Proposed Budget for Fiscal Year 2013 and average weekday passenger miles results from the demand modeling efforts for the Sepulveda Pass Corridor Systems Planning Study. Based on these inputs, average annual operating costs for the two rail options (LRT and heavy rail) included as part of Concept
5, ranged from an estimated $142M per year for light rail operations to $188M per year for heavy rail operations.

2.5.3 Issues for Further Investigation and Analysis
Construction of the portal location will require laydown areas that may impact property and require right of way acquisitions. The portal would be a flared box construction until it reaches the minimum cover required for tunnels which is generally one tunnel diameter, or somewhat less, depending on ground conditions. The box would flare to reach the full width of the track center to center of 39’. Further geologic studies would determine the actual portal dimensions and shape. Further analysis is needed regarding possible portal configurations in order to examine favorable construction staging schemes that would minimize right-of-way requirements and reduce traffic impacts and lane closures.

Siting of a new maintenance and yard shop facility may be challenging within the corridor’s highly developed urban area.
2.6 Toll Tunnel and Rail Tunnel

Concept 6 would be very similar to Concepts 4 and 5, as it consists of a bored highway tunnel through the Santa Monica Mountains and also includes a second tunnel for a private shuttle/rail service.

The proposed highway tunnel would be longer than that proposed for Concept 4, with the northern portal at approximately Roscoe Boulevard and the southern portal in the LAX area, near Century Boulevard. From Roscoe Boulevard to US-101 the highway tunnel would consist of one lane in each direction. A second lane would be added in the southbound direction coming from eastbound US-101, while a northbound lane would exit to westbound US-101 from northbound I-405. The highway tunnel would consist of two lanes in each direction from US-101, south across Sepulveda Pass and to the southern portal near LAX.

The private shuttle/rail tunnel would be shorter than that proposed for Concept 5, with a northern terminus at the Van Nuys MetroLink Station and a slightly more direct route to the Century Aviation Station that roughly parallels I-405.
Figure 8. Concept 6 Toll Tunnel and Private Shuttle/Rail Tunnel
2.6.1 Key Engineering Elements

2.6.1.1 Concept Design Elements
The primary design elements for Concept 6 for the highway tunnel structure and the tunnel portal structures near Roscoe Boulevard, US-101 and Century Boulevard, near LAX. A single tunnel portal can accommodate both entering and exiting traffic at the Roscoe Boulevard and Century Boulevard portals, but two portals are needed at the US-101 interchange, one for traffic coming to and from I-405 to the north and one for traffic coming from US-101 to the west.

The major design components associated with the private shuttle tunnel is the tunnel structure, tunnel portals, tunnel stations, light rail track, necessary associated facilities systems and a maintenance and yard shop facility.

2.6.1.2 Geotechnical Assessment
As discussed for Concepts 4 and 5, site specific geological and environmental considerations such as locations and orientation of major seismic faults, historical oil fields, favorable geological formations, widely varying ground water in the study corridor levels regime are necessary to consider when establishing a desired alignment profile for the selected routes.

As noted, the alignments are located in a seismically active region and there are numerous potentially active faults in the area and seismic hazards such as fault rupture, seismic shaking, liquefaction and landslides need to be evaluated. Seismic slope stability at portals as well as liquefaction potential of portal structures will require further evaluation. Potential displacements along the existing faults need to be evaluated during the design of the tunnels.

Other geologic hazards previously noted also apply to Concept 6, such as oil field related hazards, expansive and collapsible soils, and landslides/rock topple. Both the highway and the private shuttle tunnel designs must consider the geohazards described above. In extreme cases, special design and structures may be necessary to account for the geologic and seismic conditions that exist in the corridor. Additional information regarding geotechnical issues can be found in the Geotechnical Evaluation Memorandum (Metro, June 20, 2012).

2.6.1.3 Constructability Issues
In addition to the constructability issues noted for Concepts 4 and 5, which are also applicable to Concept 6. However, under Concept 6, at the US 101 highway tunnel portal, traffic in the northbound tunnel needs to separate into the two destinations (northbound 405 or westbound US 101) while still in the tunnel. This is expected to require the construction of cut and cover transition box structures of varying widths and
would create challenges from a constructability, right of way, and maintenance of traffic standpoint. At the US 101, at the La Grange Avenue and Sepulveda Boulevard portals, the tunnel would need to be configured to allow ingress and egress while also allowing for through traffic continuing in the tunnel. This will also create a need for a transition box structure and similar issues as stated above would need to be addressed. Further analysis is needed to determine the specific requirements for each portal and the expected temporary and permanent right of way impacts due to tunnel construction.

2.6.1.4 Rough-Order-of-Magnitude Costs
See Section 2.1.3 of this report for a brief discussion of the methodology and assumptions used when developing the rough-order-of-magnitude costs or the Sepulveda Pass Corridor Systems Planning Study Preliminary Cost Report for a more in-depth discussion.

2.6.1.5 Capital Cost Estimate
Concept 6 consists of a bored highway tunnel through the Santa Monica Mountains from approximately Roscoe Boulevard to the southern end of the Study corridor at LAX, near Century Boulevard. Concept 6 also includes a private shuttle service that would be located in either a large, single-bore tunnel, or a twin bore tunnel from Sylmar to the LAX area, with destinations and operating characteristics as for the “heavy rail” option for Concept 5.

A low range and high range estimate were developed for the tunnel portions of the alignment, with the low range cost representing a 20 percent reduction to reflect an assumed economy of scale associated a tunnel of this length. The rough-order-of-magnitude capital cost estimate for Concept 6 was estimated to have a low range of $30.8B to $38.7B.

2.6.1.6 Vehicle Cost Estimate
Vehicle cost associated with the proposed rail service for Concept 6, are included in the overall per mile capital costs discussed above.

2.6.1.7 Operation and Maintenance Cost Estimate
Operating and maintenance cost estimates were developed using the operating and maintenance costs for bus service and light rail operations as reported in the Metro Proposed Budget for Fiscal Year 2013 and average weekday passenger miles results from the demand modeling efforts for the Sepulveda Pass Corridor Systems Planning Study. Based on these inputs, average annual operating costs for the rail component of Concept 6 were estimated $104M per year.
2.6.2 Issues for Further Investigation and Analysis

As noted for Concepts 4 and 5, construction of the portal location will require laydown areas that may impact property and require right of way acquisitions. The portal would be a flared box construction until it reaches the minimum cover required for tunnels which is generally one tunnel diameter, or somewhat less, depending on ground conditions. In the case of the private shuttle tunnel, the box would flare to reach the full width of the track. Further analysis is needed regarding possible portal configurations in order to examine favorable construction staging schemes that would minimize right-of-way requirements and reduce traffic impacts and lane closures.

Another constructability issue with concept 6, similar to Concept 4 is the construction of tunnel portals and tunnel facilities near existing structures, and the need to minimize impacts to the foundations of the existing neighboring structures.

As noted for Concept 3 and 4, traffic management is somewhat more challenging for the concepts that have limited entry and exit points to the roadway facility. Further traffic analyses need to be performed to determine the traffic demand and capacity required at the proposed portal locations to better assess (tunnel and local street) operational feasibility of the concept and the access and egress locations.

Lastly, similar to Concept 5, the private shuttle tunnel would require the siting of a new maintenance and yard shop facility, which may be challenging within the corridor’s highly developed urban area.
3 NEXT STEPS

This study has identified six representative concepts. A potential outcome of subsequent studies could be the identification of other feasible alternatives, which should also be thoroughly analyzed for merit. Further studies would also establish alignments and station locations for the different transit alternatives and would establish lane configurations, ramp, and direct connector locations for freeway alternatives. Based on the conceptual engineering plans, conceptual operating plans for transit services could be established that would take into account the effects of grades, curves, and station spacing on anticipated operating speeds, as well as grade-crossing delay for any at-grade alternatives. The next steps expected to be required as part subsequent planning or environmental studies include, but are not limited to, those listed below.

At-Grade and Aerial Viaduct Options (Concepts 1, 2 and 3)

- Create basemap including titles search for proper right of way requirements assessment;
- Additional geotechnical desk study;
- Search of existing utilities records and buildings records;
- Develop preliminary ramp configurations;
- Refine cost estimate;
- Refine environmental analysis of potential impacts and mitigation;
- Refinement of demand modeling and financial analysis;
- Identify sources of funding and propose likely project delivery method;
- Perform cost/benefit analysis based on above;
- Community outreach.

Tunnel Options (Concepts 4, 5 and 6)

In addition to the items listed above for Concepts 1 through 3, concepts with tunnel sections will, at a minimum, require the following analyses and evaluations:

- Refine portal locations;
- First phase of geotechnical site investigation, including deep borings in the Santa Monica Mountains and laboratory testing;
- Reconfirm initial assessment of large diameter TBM feasibility with TBM manufacturers, based on site investigation results;
- Refine tunnel alignment, profile, and configuration;
- Develop concepts for tunnel ventilation, fire life/safety and other tunnel systems and facilities;
- Identify possible locations for fan plant buildings;
- Perform conceptual design and produce conceptual drawings for underground structures and fan plant buildings.
- Identify standard design components that can be utilized as “typicals” to reduce design, construction, and operating cost.
Appendix 1: Conceptual Drawings