COLUMBIA PIKE
STREET SPACE
PLANNING TASK FORCE REPORT

FEBRUARY 2004

ARLINGTON
VIRGINIA

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This report was accepted by the County Board on February 22, 2004. On the same date, the street space cross sections contained herein were adopted by the County Board, with subsequent minor refinements. These cross sections are subject to further evaluation and modification.

I. Introduction

In February 2003, the Arlington County Board adopted a new redevelopment tool for Columbia Pike called the Form Based Code (FBC). This was the culmination of an intensive community and staff planning process that is documented in the Columbia Pike Initiative – A Revitalization Plan (CPI), which was approved in March 2002. The Form Based Code regulates the form of land development in order to achieve the vision set forth in the CPI. Through the creation of four development nodes within the Columbia Pike Special Revitalization District, the County seeks to "foster a vital Main Street for its adjacent neighborhoods through its lively mix of uses with shopfronts, sidewalk cafes, and other commercial uses at street level overlooked by canopy shade trees, upper story residences and offices."[1]

This planned redevelopment takes place against the backdrop of Columbia Pike, a street that is an important transportation corridor. Columbia Pike is a heavily traveled state highway that carries between 30,000 and 40,000 vehicles per day along its three and a half mile length. In addition, the Washington Metropolitan Area Transit Authority's (WMATA's) Columbia Pike bus service is the busiest local bus line in Virginia, carrying about 10,000 daily riders with scheduled service less than five minutes apart during peak periods. For the long term, Arlington County is looking at higher-capacity transit along Columbia Pike, such as light rail, streetcar or rubber-tired tram.

In addition, bicycle riders have expressed a desire for better connections among the neighborhoods along Columbia Pike, attractions along the Pike itself and destinations such as the trails along Four Mile Run and the Potomac River. A look at Arlington's bicycle route map shows a lack of convenient east-west connections south of Arlington Boulevard.

Finally, while the Columbia Pike Corridor is an area of heavy pedestrian activity, the character of much of the street and its adjacent commercial areas is not always accommodating to pedestrians. Pedestrian activity is the hallmark of the Main Street environment and is only expected to increase as redevelopment according to the Form Base Code begins to materialize.

When the Form Based Code was adopted in February 2003, some specific questions regarding the street space environment required further study. The County Board appointed the Columbia Pike Street Space Planning Task Force to study these issues and to develop an end-to-end vision for the public right-of-way. The Task Force was charged to consider both land use and transportation issues in arriving at its recommendations.

The Task Force was composed of representatives from the ten neighborhoods that adjoin Columbia Pike and representatives from eight Countywide committees and commissions that have an interest in this redevelopment. Supporting the Task Force was key County staff and nationally recognized authorities knowledgeable about land use and transportation issues in a Main Street environment. Studies and analysis that project trends on Columbia Pike and address subjects that the Task Force considered are catalogued in the Appendix.

[1] Columbia Pike Form Based Code.

II. Task Force Charge

A. Objective

Develop an end-to-end vision for the Columbia Pike right-of-way from building face to building face that supports the revitalization effort to create great public spaces and accommodate a multi-modal transportation facility that will support appropriate private investment.

B. Background

The Form Based Code for the revitalization of Columbia Pike establishes the vision for the development of buildings on private property along the Pike. The development of the Code necessitated the specification of Required Building Lines (RBLs) to determine the location of future buildings. The RBLs were developed in part based on multi-modal transportation options that grew out of the public charrette and other community feedback. The purpose of this Task Force is to create a plan for the development of the public space between the RBLs and to provide a detailed review of Columbia Pike transportation alternatives and their components, including the appropriateness of the RBLs.

C. Guiding Principles

This effort shall consider the following characteristics anticipated for development along Columbia Pike, as articulated in the *Columbia Pike Initiative - A Revitalization Plan* adopted March 12, 2002:

- Mixed-use development districts (retail, office, residential, cultural)
- Street frontage at a pedestrian scale with articulated ground-floor retail
- Buildings oriented to Columbia Pike
- Placement of buildings at the back of sidewalks
- Buildings built close together forming a continuous “street wall” characteristic of an urban environment
- Parking located underground or to the rear of buildings
- Appropriate transitions to residential neighborhoods
- Enhanced public and pedestrian transportation
- Enhanced streetscape.

D. Deliverables

The Task Force shall make recommendations on the following:

- Widths and specifications for sidewalks, street furniture, bicycle parking, planting strips, transit stops, bicycle lanes, transit lanes, and vehicle travel lanes
- Evaluation of pros and cons for separate transit lanes, maintaining the flexibility for consideration of different transit options (bus vs. rail, median-running vs. curb-running)
- Evaluation of alternative locations and approaches to bicycle lanes.

E. Alternatives

The Task Force shall, at a minimum, consider the following alternatives:

- Maintaining two travel lanes in each direction with shared transit and auto use
- Maintaining two travel lanes in each direction, with one of those lanes exclusive for transit
- Maintaining two travel lanes in each direction with the addition of a dedicated transitway in the western part of Columbia Pike.

F. Membership:

- Planning Commission – Tom Greenfield
- Transportation Commission – Dennis Leach/Franz Gimmler
- Columbia Pike Revitalization Organization – Bryant Monroe/Tim Lynch
- Pedestrian Advisory Committee – Michael Goad
- Transit Advisory Committee – Harvey Berlin/Elizabeth Parker
- Bicycle Advisory Committee – Allen Muchnick
- Historic Affairs and Landmarks Review Board – Isabel Kaldenbach
- Alcova Heights Citizens Association – Lander Allin
- Arlington Heights Civic Association – Betty Siegal
- Arlington View Civic Association – Eugene Hubbard
- Barcroft School and Civic League – Randy Swart
- Columbia Forest Civic Association – Paul Benda
- Columbia Heights Civic Association – Jill Lewis/Dotsie Rowe
- Columbia Heights West Civic Association – Linda LeDuc
- Douglas Park Civic Association – Linda Dye
- Penrose Neighborhood Association – Dave Diamond/Tom Greenfield
- Claremont Citizen's Association – David Hemenway
- Neighborhood Traffic Calming Committee – Elaine Squeri

with assistance from:

- Virginia Department of Transportation – Jonathan Stowe
- Washington Metropolitan Area Transit Authority – Greg Walker/Robin McElhenny-Smith
- Arlington County Staff –
  - Patricia Bush, DES – Traffic
  - Charlie Denney, DES - Planning
  - Jim Hamre, DES - Planning
  - Richard Hartman, DES - Planning
  - Richard Tucker, CPHD – Planning

III. Task Force Goals

A. Community Vision

The recently adopted Columbia Pike Form Based Code expresses a fundamental change in the built environment of Columbia Pike. This form of development envisions a Main Street where the activities of daily life are accessible on foot, as well as by bicycle, transit and car. It moves away from the auto-oriented commercial strips and the vestiges of the arterial highway found on Columbia Pike today. The vision refocuses the street from a thoroughfare for cars and buses to a place where people live, work, shop and spend their leisure time.

The Task Force recommendations for the Columbia Pike street space seek to create an end-to-end vision for the street space that supports the Main Street environment and transforms the street space into a contributing element of a great public space.

B. Task Force Approach: Three Key Objectives

The Task Force examined the proposed uses and users of the street space and sought guidance from authorities in the fields of street design, bicycling, traffic and transit analysis, and economic development. Field experience and the objective data provided by experts in these fields complimented the considerable body of community comment gathered during the Columbia Pike Initiative process.

Based on these inputs, the Task Force identified three fundamental changes necessary to transform Columbia Pike into a Main Street pedestrian environment:

- Reduce speed of traffic
- Minimize pedestrian crossing distance, and
- Increase sidewalk space.

The Task Force recommendations in this report identify the synergy in these objectives and recognize that each acts separately and together to affect the quality of the street space.

1. Reduce Speed of Traffic

Traffic speed on Columbia Pike has been a concern raised at all of the past community forums. Excessive speed increases risk to all users, but especially pedestrians and bicyclists. To confirm community perceptions and provide objective data, a Columbia Pike Speed Study was conducted by the Department of Environmental Services over the course of a seven day period. Traffic speeds were measured at key locations and are summarized in the table on the next page.

Table 1. Columbia Pike Speed Study, June 2003

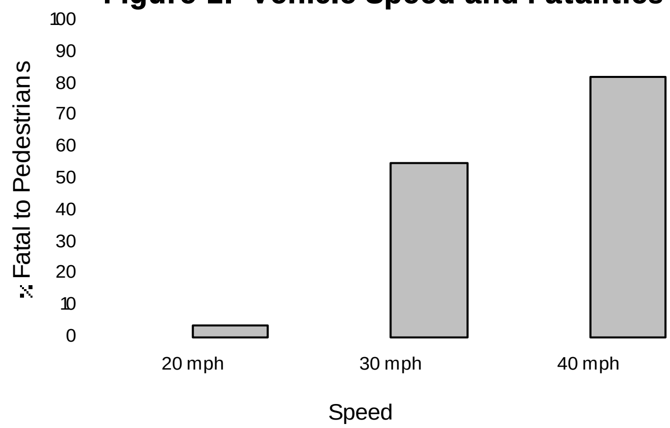
Main Street	Cross Street			Average Daily Volume	Average Speed	85th Percentile Speed	Existing Speed Limit
Columbia Pike	west of Dinwiddie St	weekday	EB	8,939*	31	39	35
			WB	15,291	28	38	35
		weekend	EB	8,794*	30	38	35
			WB	7,932*	29	37	35
Columbia Pike	west of Wakefield St	weekday	EB	15,181	29	39	35
			WB	12,142	30	42	35
		weekend	EB	14,291	28	38	35
			WB	11,822	31	41	35
Columbia Pike	east of Quincy St	weekday	EB	15,268	32	40	30
			WB	12,740	33	42	30
		weekend	EB	13,482	31	39	30
			WB	12,329	32	41	30
Columbia Pike	east of Edgewood St	weekday	EB	15,906	28	39	30
			WB	14,218	28	38	30
		weekend	EB	13,290	29	39	30
			WB	12,576	28	38	30
Columbia Pike	east of Courthouse St	weekday	EB	17,105	31	40	30
			WB	6,528*	30	38	30
		weekend	EB	13,548	32	40	30
			WB	5,363*	30	38	30
Columbia Pike	east of Oak St	weekday	EB	6,283	30	40	30
			WB	7,581	32	41	30
		weekend	EB	3,738	34	43	30
			WB	5,466	35	43	30

* data from 1 lane only

Depending on the location measured, the average speed on Columbia Pike ranged between 28 and 35 mph with the 85th percentile speed between 37 to 43 mph. The Task Force recommendations reflect the view that the range of speeds presently observed on Columbia Pike are not appropriate in a pedestrian environment. Widely published objective data show that the risk of serious injuries and fatality increases exponentially with increases in traffic speed.

Another finding of the speed study is the lack of relationship between the measured speeds and posted speeds. The average speeds measured in the study did not correspond to the two posted speeds, 30 and 35 mph. This supports the view that drivers are influenced by roadway conditions, as well as posted speeds.

Figure 1. Vehicle Speed and Fatalities



Managing traffic speed became the cornerstone of the Task Force approach to creating a Main Street pedestrian environment. Recommendations outlined through the remainder of this report are predicated on establishing travel speeds on Columbia Pike in the range of 20 to 25 mph. Traffic speeds in this range provide an important margin of safety for both pedestrians and on-street cyclists.

RECOMMENDATION 1: *Adopt a traffic speed goal for Columbia Pike of 20 to 25 mph.*

The present street design accommodates higher speed travel through wide lanes and a wider overall profile, features that provide a margin of safety to drivers at higher speeds. The Task Force recommendations address a series of design elements to lower the design speed of Columbia Pike. Among the elements the Task Force considered are:

- A narrow street profile
- Narrow travel lanes
- On-street parking
- Vertical elements that narrow the visual field
- Center medians, and
- Treatments that distinguish pedestrian space.

In addition, the Task Force recommends the following measures to further support, supplement and reinforce the reduction of speeds:

- Signal timing and progression
- Additional traffic signals
- Posted speed limits and enforcement.

Not only will lower speeds contribute to a safer environment for pedestrians and on-street bicyclists, lower speeds will reduce traffic-related noise in areas where sidewalk activity is encouraged.

2. Minimize Pedestrian Crossing Distances

Today's varying street widths on Columbia Pike provide a firsthand opportunity to observe how a few feet difference in street width can create a substantial difference in the feel of the street and the ease with which pedestrians cross.

The primary street design element that moderates speed, a narrow street cross section, supports the second Task Force objective, a shorter pedestrian crossing distance. The Task Force recommends a narrow crossing distance to shorten the pedestrian crossing time.

Current County guidelines establish the maximum single crossing distance at 60 feet. In a number of places on Columbia Pike this distance is exceeded and requires pedestrian refuges in the center of the roadway. The Task Force recommendations call for keeping the pedestrian crossing distance well below the maximum County guideline. A narrow pedestrian crossing is also essential in supporting pedestrian movement in the retail environment envisioned in the overall plans for Columbia Pike. To further support pedestrian movement and safety, the Task Force recommends minimizing the curb return radii at intersections, which will reduce travel speeds for turning vehicles and reduce the crossing distance for pedestrians.

RECOMMENDATION 2: *Maintain a pedestrian crossing distance that is appropriate for safe, efficient passage and that supports a street design that will achieve the target speed goals.*

RECOMMENDATION 3: *Establish the pedestrian crossing distance at 54 feet in the activity centers.*

RECOMMENDATION 4: *Establish a standard for curb return radii of 15 feet at intersections.*

3. Increase Sidewalk Space

The third overall objective of the Task Force was to create sidewalk space sufficient for all of the uses common to a pedestrian Main Street environment. In addition to the primary purpose of the sidewalk to provide a pedestrian pathway, the overall vision for Columbia Pike includes shopping, dining, and accessing transit. Special note was taken of the needs of disabled pedestrians.

RECOMMENDATION 5: *Adopt a sidewalk specification that supports the pedestrian Main Street environment.*

The Task Force recommendations rebalance the public right-of-way to give more space to pedestrians.

IV. Street Space Recommendations

A. General

The Task Force considered each element of the street space individually and as part of the working whole. The cartway, including travel lanes, left turn lanes, medians, transit lanes, bike lanes, and the sidewalk, including tree pits/planting strips and on-street parking, were examined in terms of overall dimensions, surfaces, and amenities.

Conceptually the Task Force divided Columbia Pike into three parts: the activity centers that correspond to the four revitalization areas covered by the Form Based Code, the Western Gateway, the Neighborhood Center, the Village Center and the Town Center; the areas between the activity centers; and both ends of Columbia Pike, which are designated as gateways. In the far west, the Western Gateway is both an activity center and gateway area. In the Town Center, the Task Force also gave special consideration to the proposed civic square between Cleveland and Barton Streets and to a two block area containing historically designated buildings.

The remainder of this section discusses existing conditions and the Task Force recommendations for the cartway and sidewalk. The street space cross section drawings, which follow, show the recommended street space configuration for the entire length of Columbia Pike.

1. Cartway

Presently there is great variability in the width of the cartway on Columbia Pike, defined as the area between the two curb faces. These extreme variations in the street width can be found even within the space of one or two blocks.

The present street widths in the activity centers summarized below and in Table 1. are representative of the range in street widths throughout Columbia Pike:

- Town Center - 51.5 to 57.5 feet
- Village Center - 50 to 69.5 feet (measured at George Mason Drive)
- Neighborhood Center - 50.5 to 54 feet
- Western Gateway - 66 to 100 feet (measured at opposing bus pull-offs).

Achieving a compact cartway is integral to the Task Force objectives of managing speeds and minimizing the pedestrian crossing distance. The Task Force recommendations for the cartway seek to minimize the width of the street. In general, the cartway width should be as narrow as possible, the existing cartway width should not be increased, and the cartway width should be decreased where excessively wide.

The overall width of the cartway depends on the number and size of the elements (which include the number and width of travel lanes, medians, and possible exclusive transit or bicycle lanes) within the space. The Task Force sought to minimize the cartway by limiting the number and width of each of the elements.

Table 2. Columbia Pike Dimensions

	north											south		
LOCATION	side walk	plant strip	gutter pan	outside lane	inside lane	turn lane	median	inside lane	outside lane	gutter pan	plant strip	side walk	curb to curb	notes
Quinn (west leg)	5.5 (ft.)	4.5 (ft.)	2 (ft.)	25 (ft.)	- (ft.)	- (ft.)	- (ft.)	10 (ft.)	12 (ft.)	- (ft.)	- (ft.)	5 (ft.)	50.5 (ft.)	lane painting not complete
Wayne (west leg)	9.5	-	2	11	11	10	-	10.5	10	2	-	10'5	57	
Cleveland (east leg)	13	-	2	11	11	10	-	11	11	2	-	9.5	57.5	access road along south sidewalk
At CPRO	13	-	2	11	11	10	-	11	11	2	-	6	57.5	
Walter Reed (east leg)	12	-	2	11	11	10	-	11	11	2	-	17	57.5	
Walter Reed (west leg)	10	-	2	11	11	10	-	11	11	2	-	10.5	57.5	
Highland (at Mobil)	4.5	5.5	-	17	11	-	-	11	16.5	2	-	7	60.5	
Highland (at SunTrust)	5	5	-	11	11	-	-	11	11	-	-	5	51.5	8.5" parking lane on north
Monroe (west leg)	4.5	-	2	11.5	11.5	-	1	11.5	11	2	-	9.5	50.5	
Quincy (east leg)	6	4.5	2	15.5	11	-	2	11	11	2	3.5	5	58	
Quincy (west leg)	5	4	2	12	11	-	2	11	18.5	2	-	11	61	
G. Mason (east leg)	6	4.5	2	11.5	11	10.5	-	11	12	2	4	5	61	
G. Mason (west leg)	6.5	3.5	2	11	11.5	10.5	-	11	11	2	3.5	6	69.5	10' right turn lane on south side
G. Mason (south leg)	6.5	4	1.5	18	11	10.5	10	11.5	16	1.5	4.5	6	42.5, 31	measured east to west; median includes 1.5' gutters
G. Mason (north leg)	4.5	3	1.5	17	10	11	9	11	12	1.5	4	6.5	30.5, 47.5	measured east to west; median includes 1.5' gutters; 10.5' right turn lane
Taylor (east leg)	6	-	2	11	11	-	2	11	11	2	-	3	50	
Taylor (west leg)	5	-	2	11	11	-	2	11	11	2	-	5	50	
Wakefield (east leg)	5	-	2	11	11	-	2	11	11	2	-	6.5	51	retaining wall along south sidewalk
Buchanan (east leg)	4	2.5	2	11	11	-	2	11	11	2	-	4.5	50.5	
Four Mile Run Bridge	8	-	-	14	12	-	-	12	14	-	-	5	52.5	
At the Carlyle	6	-	2	11	11	10.5	-	11	11	2	-	6.5	100	17' bus pulloff on north, 23" on south
Greenbrier (west leg)	8	-	2	11	11	-	-	11	11	2	3	4	66	15.5" right turn lane on south
Jefferson (east leg)	6	-	2	26	11	10.5	6	10.5	11	2	-	4.5	41.5, 51	26" acceleration lane on south

Note: Curb width included in dimension of adjacent sidewalk or median.

a. Travel Lanes

A major source of the variability in cartway widths on Columbia Pike is the variability in the lane configuration. The minimum lane profile on Columbia Pike is four lanes, two travel lanes in each direction. At various points one or more of the following are included: left turn lanes, parking lanes, right turn lanes, acceleration lanes, and bus pull-offs. From end-to-end the lane configuration of Columbia Pike ranges from four lanes at its narrowest point to more than six lanes at the widest.

The Task Force recommends a consistent five-lane cartway the length of Columbia Pike. The recommended configuration consists of two travel lanes in each direction and a center lane that alternately serves as a dedicated left turn lane or a center median.

RECOMMENDATION 6: *Establish a uniform cartway consisting of five lanes, including two travel lanes in each direction, and a center lane that serves as a median or a left turn lane where needed.*

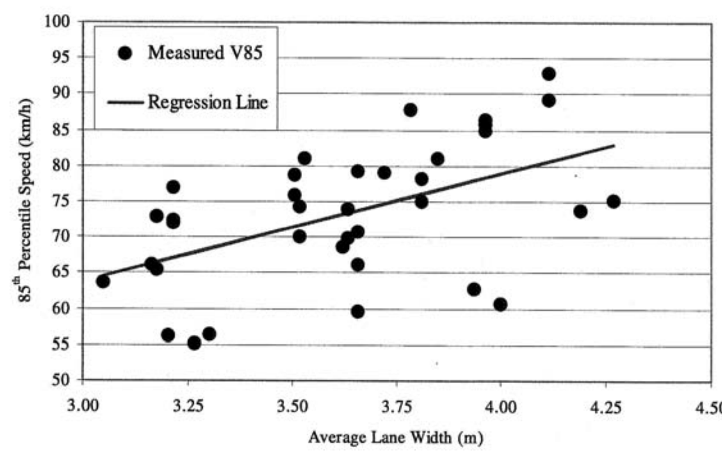
b. Lane Width

The width of travel lanes on Columbia Pike is equally variable. Curb lane widths generally range from 11 feet to 18 feet, but also include a 25 foot bus pull-off and a 26 foot acceleration lane at certain locations. The gutter pan along the curb adds one and a half to two feet more. Inside lanes are generally 11 feet wide and left turn lanes are about 10 feet wide.

RECOMMENDATION 7: *Establish lane widths at 10 feet.*

Establishing a new lane width standard is an essential. Expert presentations and literature surveys establish a relationship between lane width and speed and reinforce the view that narrow travel lanes are necessary in a street where speeds will be managed. Figure 2. summarizes research gathered on the effect of lane width on travel speeds. Results of a literature review by Parsons Transportation Group on this subject requested by the Task Force are summarized in Appendix B.

Figure 2. Speed vs. Lane Width



The Task Force recommendations reorient Columbia Pike from an arterial highway to an urban street with significant pedestrian activity.

c. Medians

Center medians with trees break up the expanse of pavement and provide vertical elements that visually narrow the roadway to help manage speeds. The use of tree lined medians wherever possible will create an aesthetic that will also help define the street as part of a great public space. Where needed, the median space can provide left turn lanes.

RECOMMENDATION 8: *Include planted medians wherever possible and use this space for left turn lanes only when justified by traffic analysis.*

Presently mid-block driveways limit the use of continuous medians, but as blocks redevelop according to the Form Based Code, the opportunities for medians will increase. The trees envisioned for the median are large species that provide a canopy as they mature and provide shade in the summer, contributing to a more comfortable environment for all users.

RECOMMENDATION 9: *Avoid placing medians where they would eliminate or restrict turning movements to and from side streets.*

d. Transit Lanes

As an interim transit improvement, a restructuring of the local bus service, called Pike Ride, was carried out in September, 2003. The initiation of Pike Ride increased service frequency, provided an optional connection to Metrorail at Pentagon City, and replaced some neighborhood Metrobus routes with Arlington Transit. Additional improvements to the Columbia Pike bus service are being planned, including enhanced bus stops and shelters and improved passenger information systems. The County also has a project underway that will give transit vehicles priority at traffic signals along Columbia Pike, advancing the green light or delaying the red to enable buses to operate closer to schedules.

For the long term, Arlington County is looking at higher-capacity transit along Columbia Pike, such as light rail, streetcar or rubber-tired tram. While existing transit operates in mixed traffic the Task Force was asked to consider whether exclusive transit lanes should be provided for future higher-capacity transit.

Parsons Transportation Group conducted traffic simulation modeling studies to evaluate three alternative street configurations. The Task Force established operational guidelines for this analysis.

The alternatives and parameters are summarized below:

- Evaluate shared vs. exclusive transitway
- Evaluate curbside vs. median transitway
- Evaluate one vs. two lanes for autos
- Model only BRT, not LRT
- Model the effects of slower speeds
- Model the morning rush hour.

Traffic analysis and transit modeling show that exclusive transit lanes in the western part of Columbia Pike would provide no significant improvement in either transit or auto travel times compared to transit running in mixed traffic. The analysis also concluded that auto travel time would increase dramatically if confined to only one travel lane in each direction.

RECOMMENDATION 10: *Maintain a five-lane cross section the entire length of Columbia Pike with transit operations running in mixed traffic.*

In addition, the Task Force recommendations assume a curb running transit system and locate the transit stations on the sidewalk. A median running system would require an overall wider cartway in order to accommodate transit platforms in the median and would likely increase the overall dimensions of the street space.

RECOMMENDATION 11: *Establish transit operations in the curb lane, running in mixed traffic, with transit stations located on the sidewalk.*

The Task Force recommendations would accommodate either a light rail system or a bus rapid transit system. A complete report of the transit and traffic modeling can be found in Appendix C.

e. Bicycle Lanes

Presently there are no bike lanes on Columbia Pike. Bicycle traffic is generally limited to expert or advanced riders moving with traffic in the curb lane. The Columbia Pike Initiative plan also identified parallel routes along Columbia Pike that provide some additional east-west travel.

The Task Force recommends on-street bike lanes east of Courthouse Road and west of Frederick Street. In these areas, the pattern of development and/or topography severely limits the development of parallel bike routes.

RECOMMENDATION 12: *Include on-street bike facilities east of Courthouse Road and west of Frederick Street.*

The recommended on-street bike lanes in the west end are striped off spaces next to the valley gutter adding an additional three feet adjacent to the curb lane. While the recommended shared transit lane width is 10 feet, there may be locations where an additional one foot of lane width is required due to dynamic motion of transit vehicles at some locations. A street configuration that would increase the pedestrian crossing distance beyond the 60 foot County standard is not recommended as a general configuration. In addition, west end bike lanes may require reevaluation based on the needs of a future transit system.

Adding on-street bike lanes in the activity centers, either the standard five foot bike lanes or widened curb lanes, works against the Task Force goal of maintaining a narrow cartway and significant reduction in traffic speeds. Further, studies provided by national experts show that target traffic speeds of 20 to 25 mph may provide safe biking on Columbia Pike for advanced riders, although the volume of traffic will discourage most riders from using the street.

In addition to cartway dimensions, the Task Force has reservations about the effect of bike lanes on pedestrian crossing distances, transit operations, and the dedication of right-of-way for a use that might not prove popular enough to justify the design.

The Task Force recognizes that a decision to provide neither bike lanes nor wide outside lanes on Columbia Pike from Courthouse Road to Frederick Street requires a serious commitment by the County to extend and upgrade parallel on-street bike routes on both 9th Street and 12th Street, on either side of the Pike, and makes the following recommendations for bike routes through nearby neighborhoods.

RECOMMENDATION 13: *Extend and upgrade parallel on-street bike routes between Frederick Street and Courthouse Road.*

RECOMMENDATION 14: *Install traffic signals to facilitate bicycle crossings of South Glebe Road and South Walter Reed Drive at both 9th Street South and 12th Street South.*

RECOMMENDATION 15: *Study the feasibility of opening 9th Street South to two-way bicycle traffic from South Glebe Road to South Irving Street.*

RECOMMENDATION 16: *Study the feasibility of extending parallel bike routes west of their currently feasible termini at South Quincy Street and east of their currently feasible termini at South Cleveland Street (12th Street South) or South Wayne Street (9th Street South), including the construction of at least three bicycle and pedestrian bridges to cross Four Mile Run and Doctor's Run at 9th Street South and to connect South Barton Street and South Wayne Street at 12th Street South.*

The Task Force concludes that the constrained roadway dimensions required to reduce vehicle speeds and enhance the pedestrian environment does not allow room for bicycle lanes in the activity centers. While these parallel routes are proposed for the Columbia Pike corridor, in general, parallel routes are not a full substitute for separate bicycle accommodation on the main thoroughfare.

2. On-Street Parking

Presently, on-street parking is permitted only in two short sections, on the north side of Columbia Pike west of South Highland Street, and on the north side of Columbia Pike between South Oakland Street and South Quincy Street. The Task Force supports adding street parking as a key tool for achieving the pedestrian, Main Street environment. Parking helps to manage speeds, provides a buffer between pedestrians and moving traffic and has been shown to promote commerce by providing convenient access for shoppers.

RECOMMENDATION 17: *Establish a pattern of on-street parking that intersperses parking spaces between trees pits extended from the sidewalk.*

Alternating trees with parked cars further supports the goal of slowing traffic speeds by maintaining a narrow street profile regardless of whether the parking spaces are filled. This tree alignment strategy also minimizes negative impacts to the trees, such as soil compaction and car doors striking the trees, as would happen if the trees were placed adjacent to the on-street parking. At the corners, the nubs that surround the parked cars also serve to significantly minimize pedestrian crossing distance.

The Task Force also supports the use of valley gutters along the outside of the parking lane. By moving the gutter from the inside of the parking lane to the outside, a buffer area is added between cars and the curb lane without adding extra width. In addition, the parking spaces should be constructed to allow drainage to flow towards the valley gutter, which will eliminate the risk of localized flooding.

RECOMMENDATION 18: *Utilize valley gutters between the parking lane and the curb lane.*

3. Trees

Trees in the medians and on the sidewalk provide a comfortable environment for pedestrians, soften the streetscape's hard edges, and are among the vertical elements that enclose the street space and act on traffic speeds. In most cases, the trees are located in tree boxes located on the sidewalk.

RECOMMENDATION 19: *Plant large species street trees on all sidewalks and all medians throughout Columbia Pike.*

4. Sidewalks

Presently, in most commercial areas in the corridor, the shops and businesses are set well back from the street, with pavement and parking located between the sidewalk and the building fronts. Pedestrians going from store to store often must go through a parking lot to reach the sidewalk or walk through rows of parked cars to get to adjacent shops.

Also, connections between the commercial areas and adjacent neighborhoods are sometimes made difficult because of long blocks without cross streets. The high volumes of traffic, moderately high speeds, varying street width and long distances between some signalized pedestrian crossings all add to the discomfort pedestrians feel when crossing the street. The high number of curb cuts and driveways and the several offset intersections mean that cars can come from unexpected directions and may not be visible to pedestrians until the last second.

Improvement in these areas is expected as the corridor redevelops according to the Form Based Code and buildings are placed at the back of the sidewalk, parking lots are placed behind buildings, and the number of curb cuts are reduced.

Finally, sidewalk dimensions on most parts of Columbia Pike are substandard and not suited to present and planned pedestrian activity. As observed in the cartway, sidewalks are also subject to wide variability in width and configuration. Sidewalks range from three or four feet to a maximum of 13 feet in the commercial area around Walter Reed.

The use of planting strips to create additional space between pedestrians and cars varies widely as well. Some sections have relatively wide sidewalks, separated from traffic by trees and/or planting strips. Other sections have narrow sidewalks directly adjacent to fast moving traffic, with broken or uneven pavement, obstructed by poles and other objects.

Most sidewalks along Columbia Pike do not meet the County minimum width of six feet recommended in the areas of moderate pedestrian travel, as called for in the Arlington County Pedestrian Plan.

The Task Force recommends significantly wider sidewalks throughout but especially in the activity centers where increased pedestrian uses are expected. These uses include walking to destinations and transit, shopping, and leisure activities such as sidewalk dining. The sidewalks must also be wide enough to include room for amenities such as street lights, art, benches, trash containers, parking meters, bicycle parking and way-finding signs. Other critical uses for the sidewalk are bus stops, bus shelters and future transit stations.

RECOMMENDATION 20: *Establish overall sidewalk dimensions in the activity centers as follows:*

- *Mid-block dimension of 14 feet 8 inches*
- *Corner dimension of 21 feet 8 inches*
- *Curb return radii of 15 feet at intersections.*

In addition, all of the different sidewalk uses must be organized so as not to interfere with the sidewalk's primary purpose as a passageway for pedestrians. To assure that all uses are given appropriate and designated space, the Task Force recommends organizing the sidewalk into specific zones of use.

RECOMMENDATION 21: *Organize the activity center sidewalk space into three distinct zones.*

- *Shy Zone - The space along the building wall (2 foot minimum)*
- *Clear Zone - The primary pedestrian space (6 foot minimum)*
- *Furniture Zone - The location for amenities (6 foot maximum).*

The Task Force approach to sidewalk design was to "keep it simple." Basic function and good design were considered more important than elaborate features and decoration.

a. Street Furniture

The Task Force recommends the use of high quality street furniture that is comfortable, durable and generally suited to a pedestrian environment. Under the provisions of the Form Based Code it is the responsibility of the developer to provide these furnishings within the activity centers.

RECOMMENDATION 22: *Develop a catalog of approved street furniture.*

b. Pavement

Paving materials for sidewalks should be selected for the comfort and safety of pedestrians. The Task Force recommends the use of smooth pavement on the sidewalk surfaces in the clear zone, but requires that a decorative pavement treatment be used in the shy and furniture zones. This provides an opportunity to create a distinctive look for each of the four activity centers.

RECOMMENDATION 23: *Develop a sidewalk treatment and street pavement style manual with a unique and distinctive treatment for each activity center.*

The Task Force also recommends alternate paving materials for the street where special care is needed to distinguish the street space as a pedestrian environment. Pavement treatment of this type would be appropriate in parts of the activity centers, such as the site of a community center and bike trail crossings in the Neighborhood Center, and the Civic Square in the Town Center.

c. Transit Stations

Another key function of the sidewalk is as a platform for transit riders. The sidewalk presently includes space for people waiting at bus stops and bus shelters and in the future will be the location of more substantial transit stations. The design of the sidewalk and the transit station must be considered together to ensure that the needs of all users are satisfied.

The design elements that help manage traffic speeds should be incorporated into the design of transit stations. Wherever possible, transit stop improvements should preserve opportunities for street trees and on-street parking while meeting operational goals.

RECOMMENDATION 24: *Limit the transit station length wherever possible in order to preserve tree placement and parking*.

RECOMMENDATION 25: *Incorporate trees in the design of transit stops in order to preserve the benefits trees provide in managing traffic speeds.*

RECOMMENDATION 26: *Place trees on the leading edge of each corner that has a transit stop in order to preserve a narrow visual field.*

RECOMMENDATION 27: *Involve the Task Force or a subset of the Task Force in the design process for the future transit stop/station improvements*.

RECOMMENDATION 28: *Include the concepts and principles outlined in the Task Force report in locating and designing shelters, taking special care to preserve the pedestrian clear zone.*

B. Street Space

1. Activity Centers

a. General

In the activity centers the overall street space is measured from building face to building face and is established in the Form Based Code by the Required Building Line, or RBL. Included in the street space are all the elements of the cartway, parking and sidewalk. The location is the result of all the decisions made about the cartway, parking and sidewalk, and it is key to defining the street space.

RECOMMENDATION 29: *Establish the overall RBL for the four activity centers at 98 feet 4 inches.*

b. Historic Town Center

A section of the Town Center, bounded by Walter Reed Drive on the west and Cleveland Street on the east, is the site of several buildings of historic significance. In this area the overall street space is narrow because of existing buildings that, in all likelihood, will remain a part of the Columbia Pike character. The recommended cartway in this area remains the same five-lane configuration used in all of the activity centers, but the sidewalk dimension is reduced to create a more uniform pedestrian area.

RECOMMENDATION 30: *Establish the RBL for the historic Town Center at 92 feet, reducing the sidewalk width to 12 feet.*

c. Civic Squares

A public square in the Town Center is planned between Cleveland and Barton Streets. This square is expected to become an active community center with heavy pedestrian traffic. An alternate paving material in the street would further distinguish this area as a pedestrian center.

Figure 3. Penrose Square Concept

RECOMMENDATION 31: *Use matching surface treatments on the sidewalks and streets surrounding the future Civic Square in the Town Center called for in the Form Based Code.*

Using a unifying pavement treatment within the outdoor plaza and on the surrounding streets and sidewalks would create the visual impact of a much larger square. The edges of the space would then be defined by the building edges rather than the smaller space confined within the adjacent cartways.

RECOMMENDATION 32: *Use special pavement treatment to match the adjacent sidewalks in the Neighborhood Center between South Buchanan and South Dinwiddie Streets adjacent to the Arlington Mill Center.*

A unified paving treatment around the Arlington Mill Center and the W & OD Trail crossing would visually unify the area and make it a more apparent focal point of the Neighborhood Center.

d. Western Gateway: Frederick Street to Jefferson Street

An alternate street design is proposed for the area between Frederick Street and Jefferson Street. This includes one block west of the Neighborhood Center and all of the Western Gateway. The proposal calls for double rows of street trees and a gateway feature at Jefferson Street. The cartway is a five-lane section with a widened curb lane to provide an on-street bike facility.

RECOMMENDATION 33: *Create a gateway feature such as a traffic circle or enlarged median at the Jefferson Street median to mark the entrance into Arlington.*

2. In-Between Areas

The Task Force recommends streetscape treatment for the two areas between the Town Center and the Village Center and the Village Center and the Neighborhood Center. In both areas the cartway continues the uniform five-lane pattern and on-street parking is recommended.

RECOMMENDATION 34: *Extend on-street parking one block outside of each activity center to include Randolph to Oakland Streets and Wakefield to Taylor Streets.*

a. Randolph Street to Oakland Street

RECOMMENDATION 35: *Establish continuous street parking between Randolph and Oakland Streets with nubs at each corner and include a planting strip between the curb and sidewalk for street trees.*

b. Wakefield Street to Taylor Street

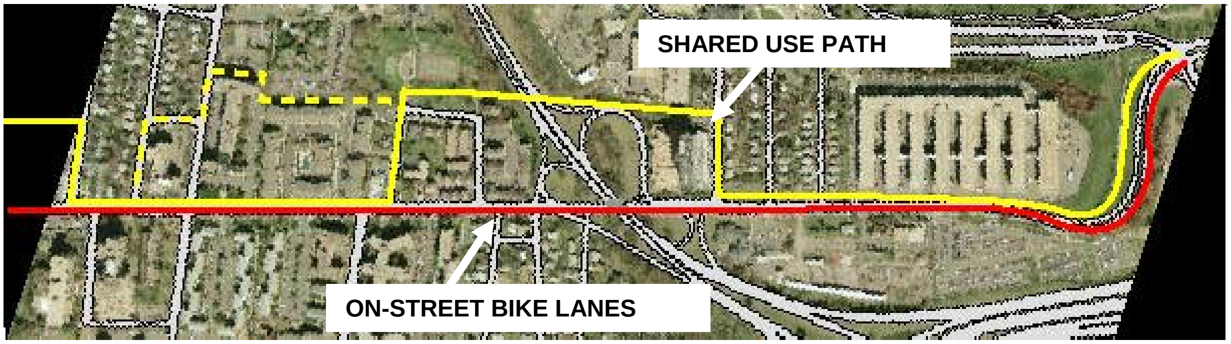
RECOMMENDATION 36: *Continue the parking and tree placement pattern from the Village Center through these two blocks to the Neighborhood Center.*

3. Eastern Gateway

The Eastern Gateway is the section east of Wayne Street to Joyce Street. This area is envisioned as a boulevard with double rows of trees in the center median and on both sides of the street. The wider median necessitates the use of a pedestrian refuge in the center. It includes both on-street and off-street bicycle facilities.

RECOMMENDATION 37: *Construct a shared-use path that would support less experienced riders such as youngsters, tourists, and other bicyclists not comfortable riding on Columbia Pike near traffic.*

Figure 4. Proposed Bicycle Routes



A shared-use path is proposed as part of the reuse of the Navy Annex site. This path would be constructed on the north side of Columbia Pike from Joyce Street to Oak Street and would allow people to bike from Joyce Street west past the Air Force Memorial, past the future Arlington Heritage Museum near Oak Street. However, a future connection across Washington Boulevard is needed.

Presently, right-of-way constraints suggest that the best way to make this connection would be a bicycle/pedestrian bridge north of Columbia Pike.

RECOMMENDATION 38: *Construct a new pedestrian bike bridge north of the Sheraton Hotel to Towers Park on the opposite side of Washington Boulevard and continue the bikeway through Towers Park to South Scott Street.*

An on-street bicycle lane could then be designated on South Scott Street as a connection to Columbia Pike and travel west to Wayne Street where riders could reach the Town Center and 9th Street South running along the north side of the Town Center.

This shared use path has a number of benefits:

- It would be a recreational asset to the Columbia Pike corridor community
- The pedestrian/bicycle bridge over Washington Boulevard would provide access to the Towers Park green space for children in Foxcroft Heights
- The bikeway could serve as a tourist attraction for visitors from within the region.

Planning for a new Washington Boulevard bridge is underway. While the detailed bridge design was outside the scope of the Task Force, the Task Force was charged with establishing the dimensions of the Columbia Pike street space at this interchange. Should right-of-way constraints be resolved, and the interchange design allow for the proposed shared-use path under the bridge span, the bicycle/pedestrian bridge concept could be revisited.

The Task Force recommendations for specific dimensions and configuration of the street space at Washington Boulevard are contained in the Quinn Street to Orme Street cross section. The Task Force recommends the careful consideration of the design of access ramps at this interchange to assure pedestrian and bicycle safety at the crossings.

RECOMMENDATION 39: *Implement design improvements at the Washington Boulevard interchange that eliminate conflicts between right-turning vehicles and pedestrians/bicyclists.*

(See Appendix A for Street Space Cross Sections)

V. Implementation Recommendations

The last several years have seen active community participation in the planning of a revitalized Columbia Pike. With recommendations for the built environment and street space articulated, the implementation of the vision is foremost in the minds of the Task Force members and the Columbia Pike community. The Task Force believes that level of interest created in planning the new environment should be encouraged and sustained and the Task Force supports the involvement of the community throughout the implementation phase.

RECOMMENDATION 40: *Establish an ongoing community work group to participate in the implementation phase of plans for Columbia Pike.*

Although implementation of some Task Force recommendations may wait for major redevelopment or new transit initiatives, various improvement projects on Columbia Pike may present themselves in the near term. In fact, a number of improvements have already been completed.

In the Town Center, new investment includes brick pavers, wide sidewalks, street trees, undergrounding of utilities, and attractive street furniture. Additional streetscape improvements are being planned or designed in the vicinity of Glebe Road and in the vicinity of Four Mile Run Drive/Buchanan Street. A current project adding a median between Columbia Street and Frederick Street should also increase pedestrian safety.

Wherever improvements are being made on Columbia Pike, their design and implementation should be in agreement with the Task Force recommendations on street space.

RECOMMENDATION 41: *Include and implement Task Force recommendations on street space in all near term street projects wherever possible.*

RECOMMENDATION 42: *Task the County Manager with producing an integrated, regularly updated implementation plan for Columbia Pike.*

The plan would provide the block-by-block details for building the cartway and street spaces recommended by the Task Force. The plan would also identify actions necessary to realign intersections, remove midblock curb cuts, improve turning radii, add traffic signals, move the center line of the street, and it would provide updates on major projects such as the Washington Boulevard bridge or the Navy Annex redevelopment.

The plan would also detail the location and status of new transit investments such as the expected Super Stop shelters and signal prioritization roll-out. For each action the plan should suggest a funding source, e.g., private redevelopment, local Capital Improvement Program (CIP) dollars, state funds, or federal monies or other sources. To facilitate the sharing of information with all interested parties, the plan should be made available through various means, including regular update meetings, newsletters, and/or the internet.

A common understanding among all parties of how the vision will be achieved and the examination of creative ways to save local public dollars will provide the support needed to make the vision a reality.

VI. Appendices

A. Street Space Cross Sections

B. Parsons Report – "Relationship Between Lane Width and Speed"

C. Parsons Report – "Columbia Pike Traffic Simulation"

Columbia Pike

Arlington County, Virginia

ARLINGTON
VIRGINIA

LEGEND MAP

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Arlington County, Virginia

North

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1"=1000 ft

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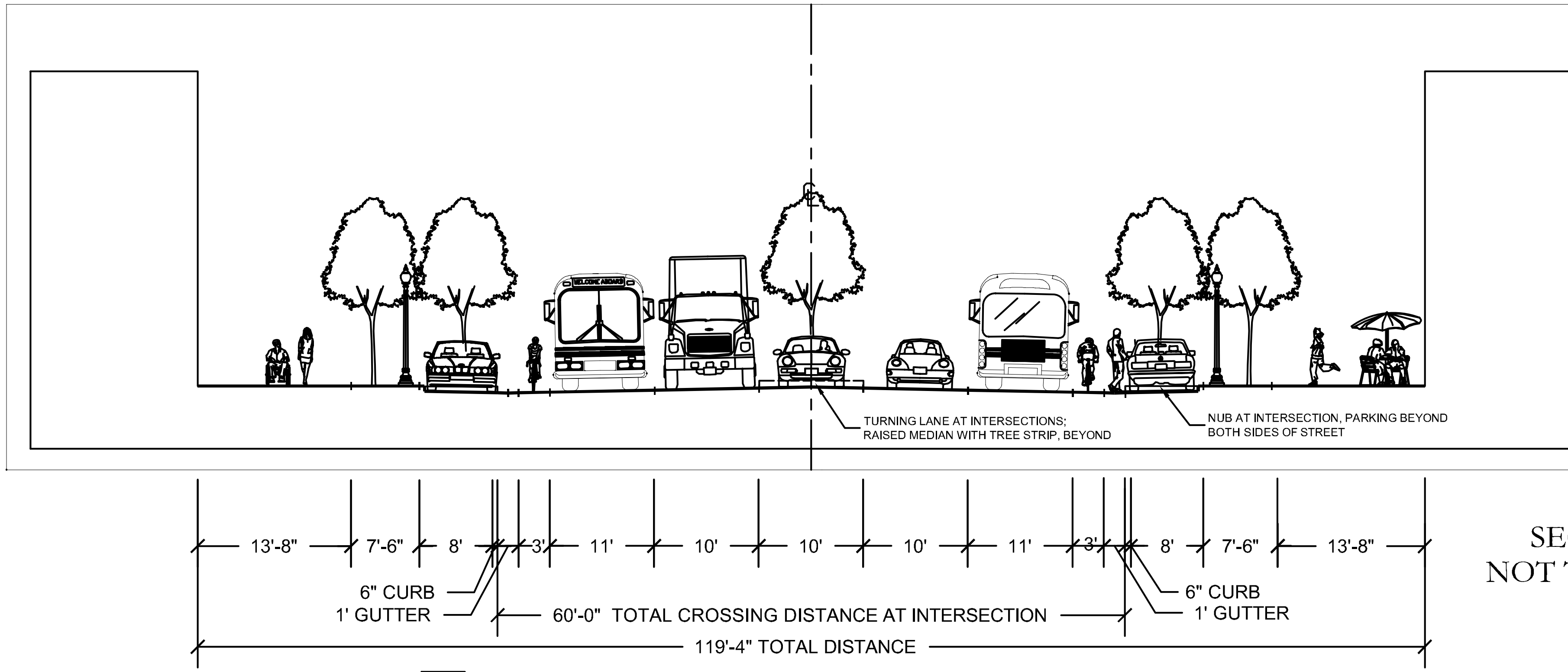


SECTION
NOT TO SCALE

Location

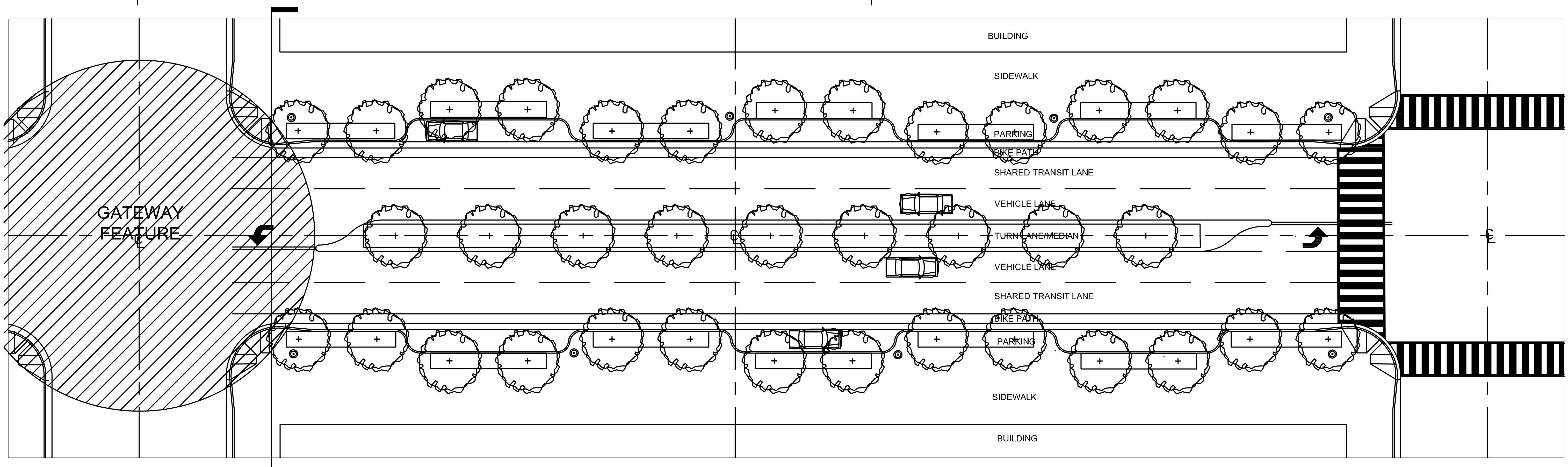
S. Jefferson St. to S. Greenbrier St.

Western Gateway
119'-4" RBL to RBL

Notes

Gateway feature to be located at South Jefferson St.

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter and 7-foot parking.



STREET PLAN

0 32' 64'

Columbia Pike

Arlington County, Virginia

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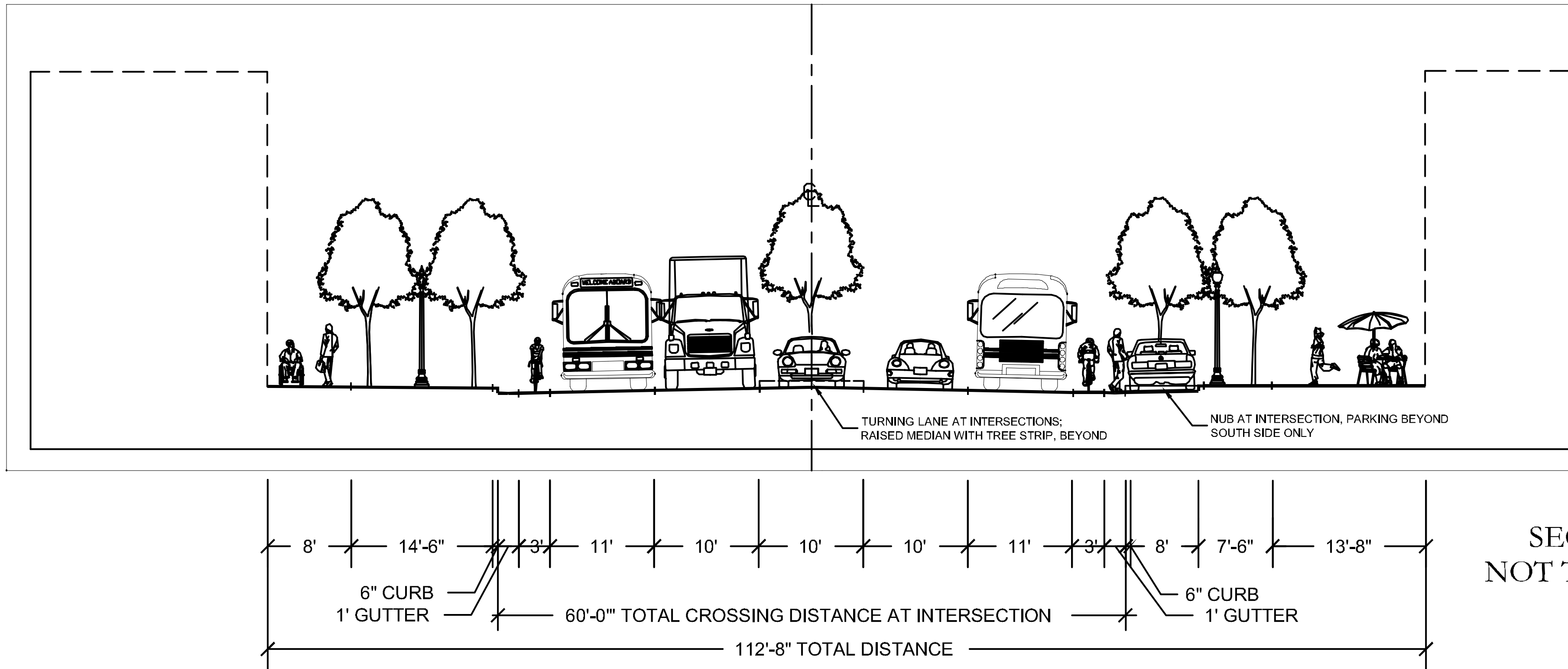

SECTION
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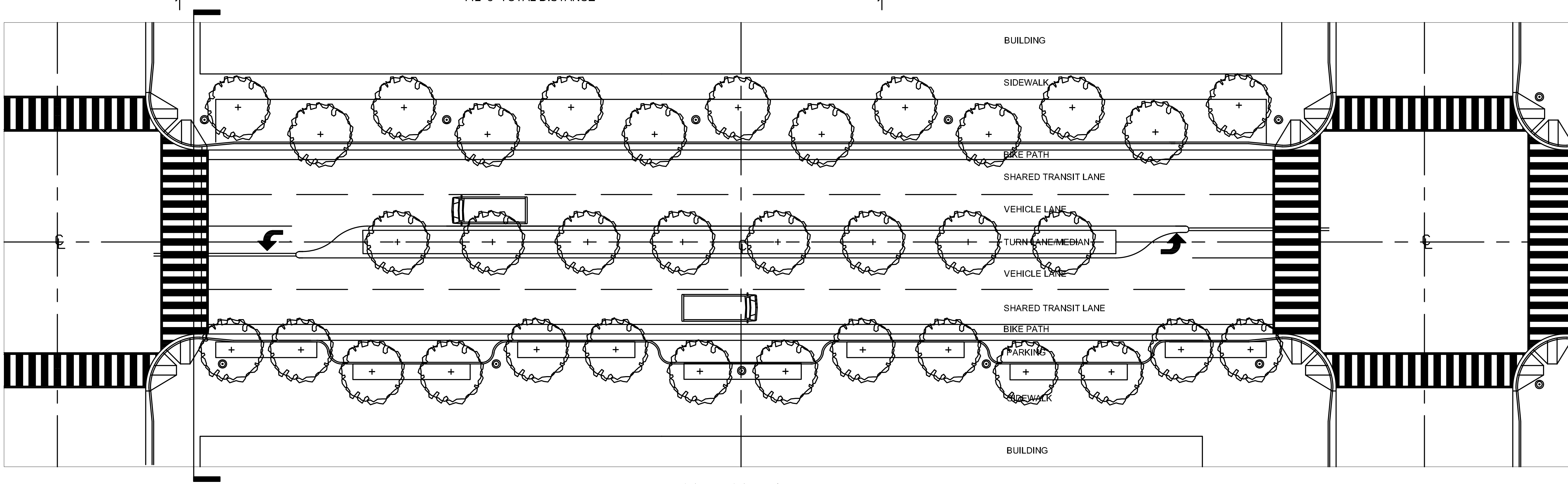
Location

S. Greenbrier St. to S. Frederick St.

In Between
112'-8" ROW

Notes

Section dimensions are shown at intersection. Mid-block has 2-foot gutter and 13-foot 6-inch landscape strip on north side, 2-foot gutter and 7-foot parking on south side.



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Columbia Pike

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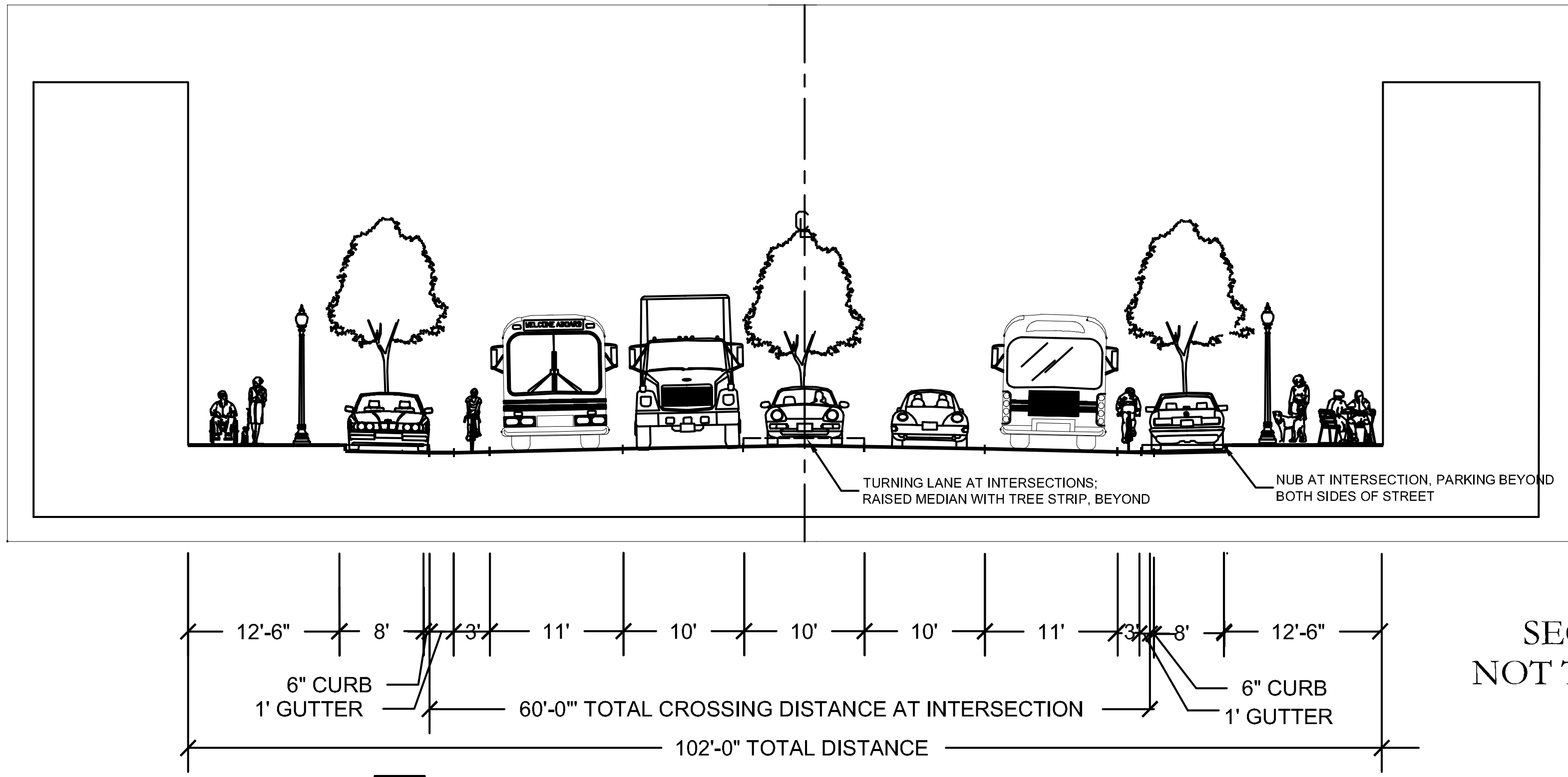

SECTION
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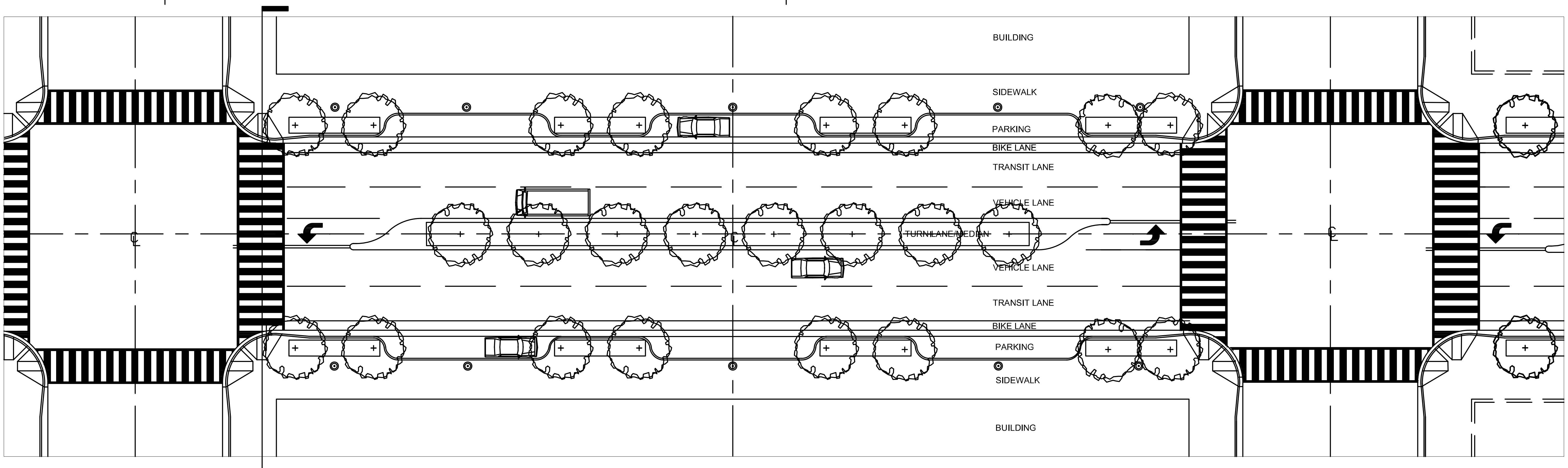
Location

S. Frederick St. to S. Columbus St.

Neighborhood Center
102' RBL to RBL

Notes

Section dimensions are shown at intesection.
Mid-block has 2-foot gutter and 7-foot parking.



STREET PLAN

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Columbia Pike

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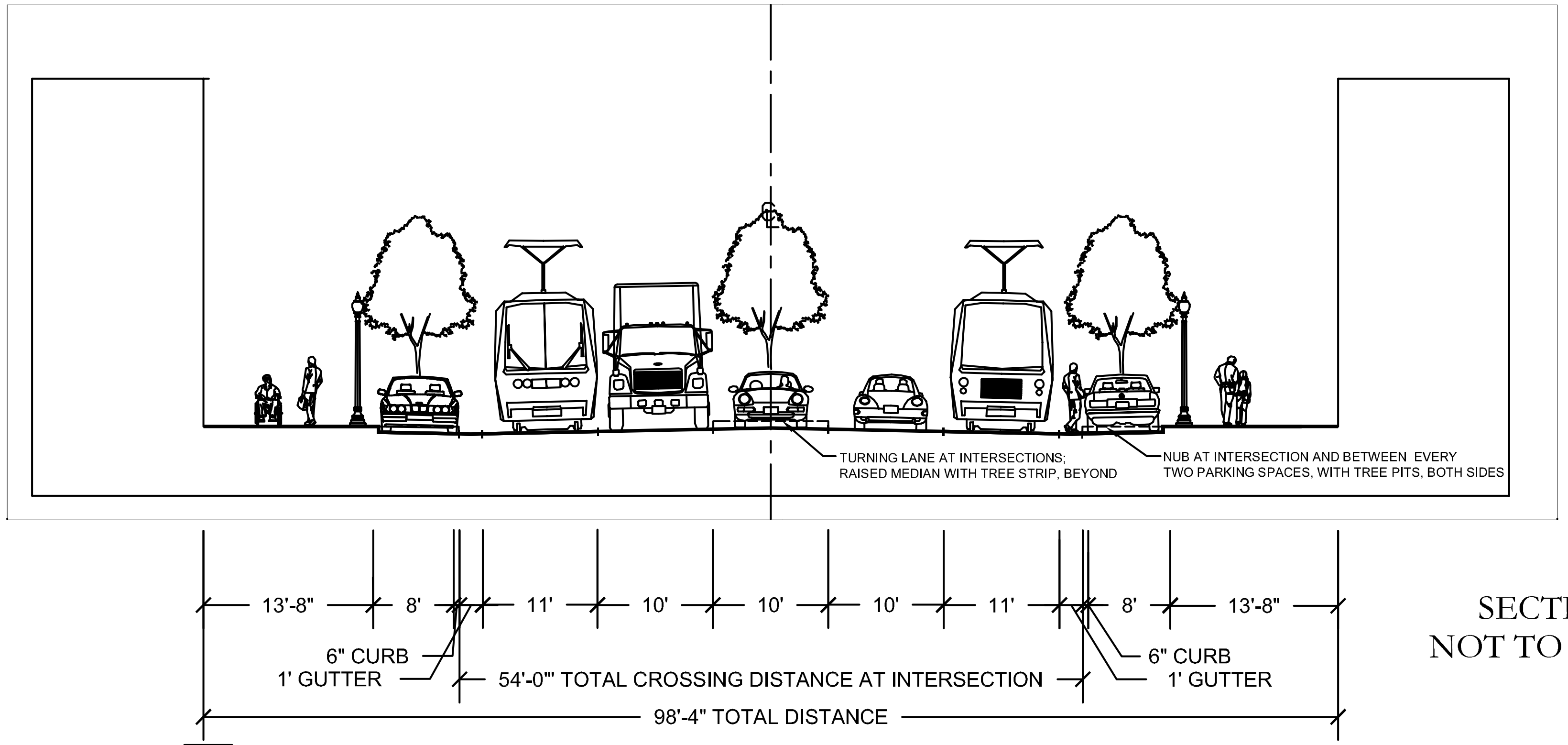

SECTION
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Location

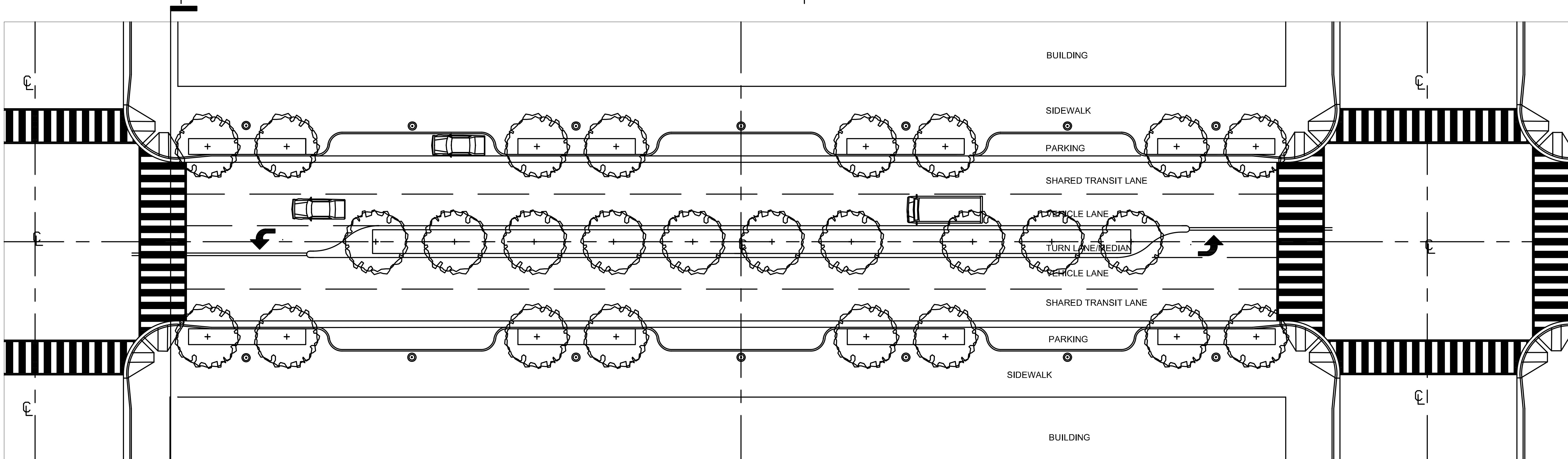
S. Columbus St. to S. Wakefield St.

Neighborhood Center
98'-4" RBL to RBL

Notes

Section dimensions are shown at intersection. Mid-block has 2-foot gutter and 7-foot parking.

Special paving treatment at Arlington Mill Community Center and W&OD bike trail.



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Columbia Pike

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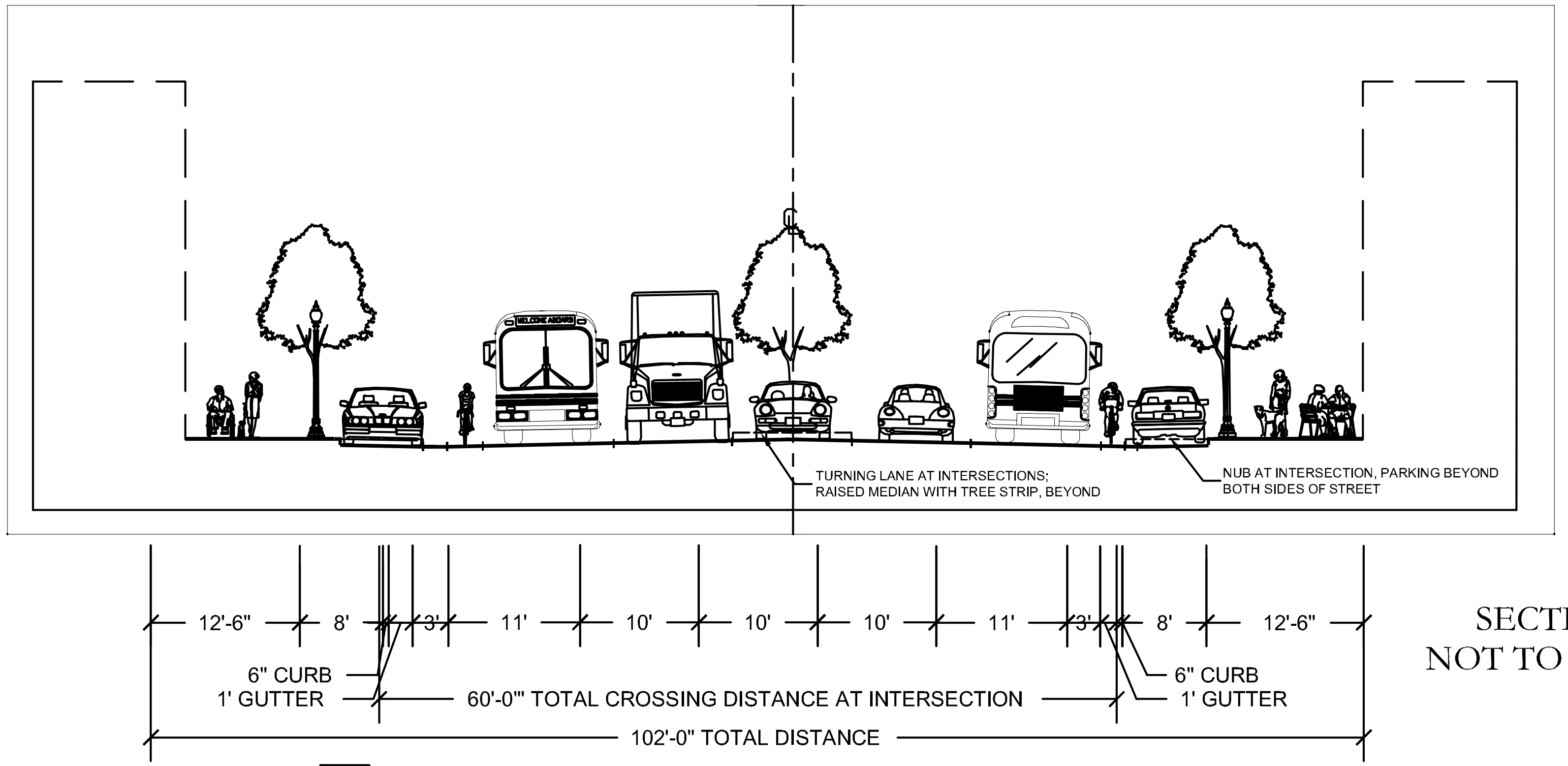

SECTION
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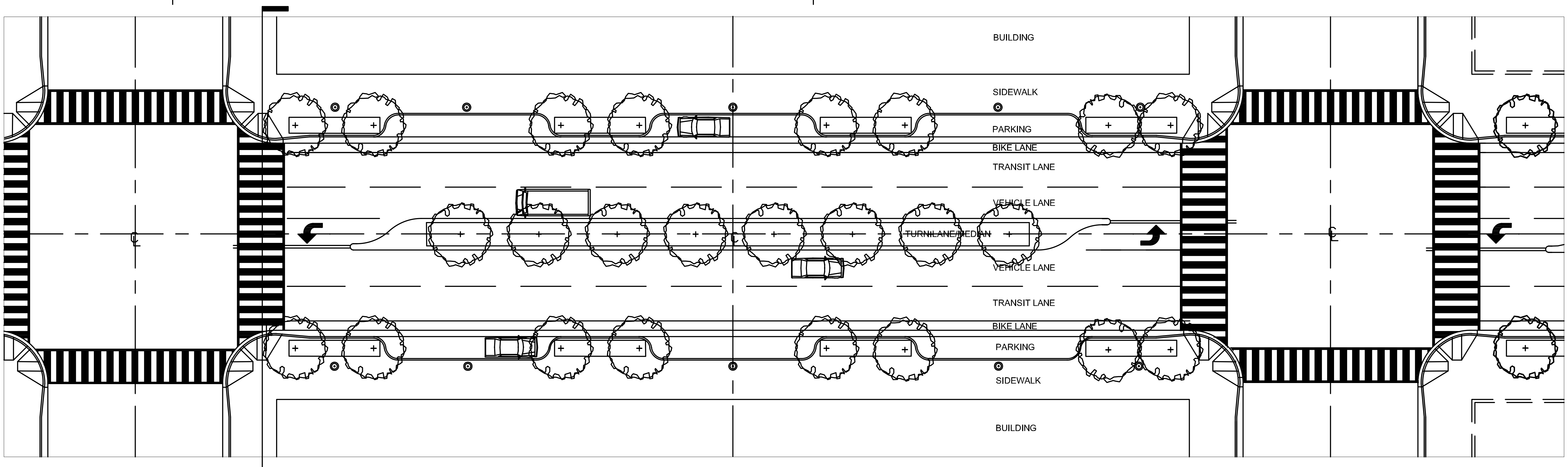
Location

S. Wakefield St. to S. Taylor St.

In Between
102' ROW

Notes

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter and 7-foot parking.



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Columbia Pike

Arlington County, Virginia

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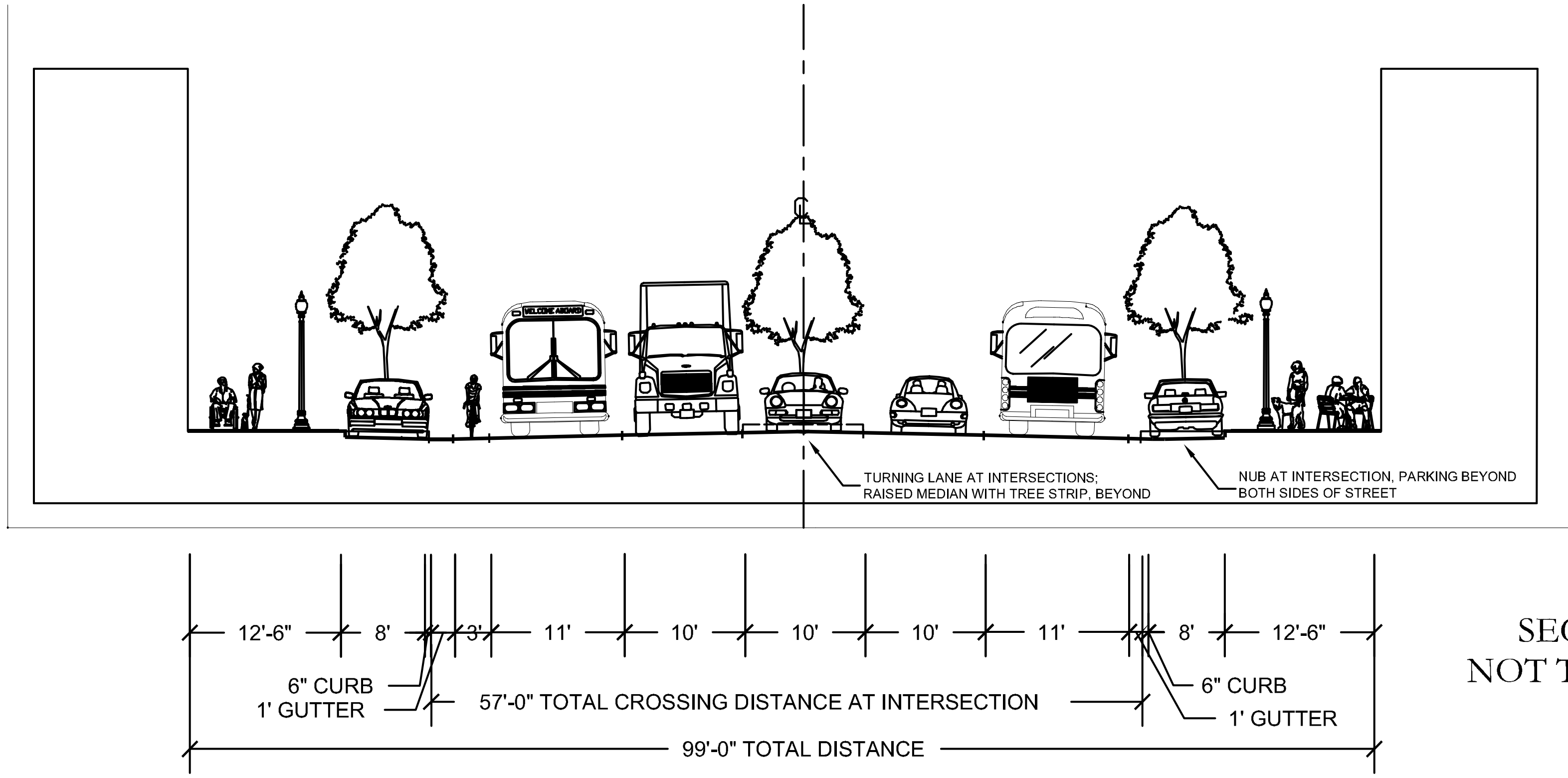

SECTION
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Location

S. Taylor St. to S. Randolph St.

Village Center
99' RBL to RBL

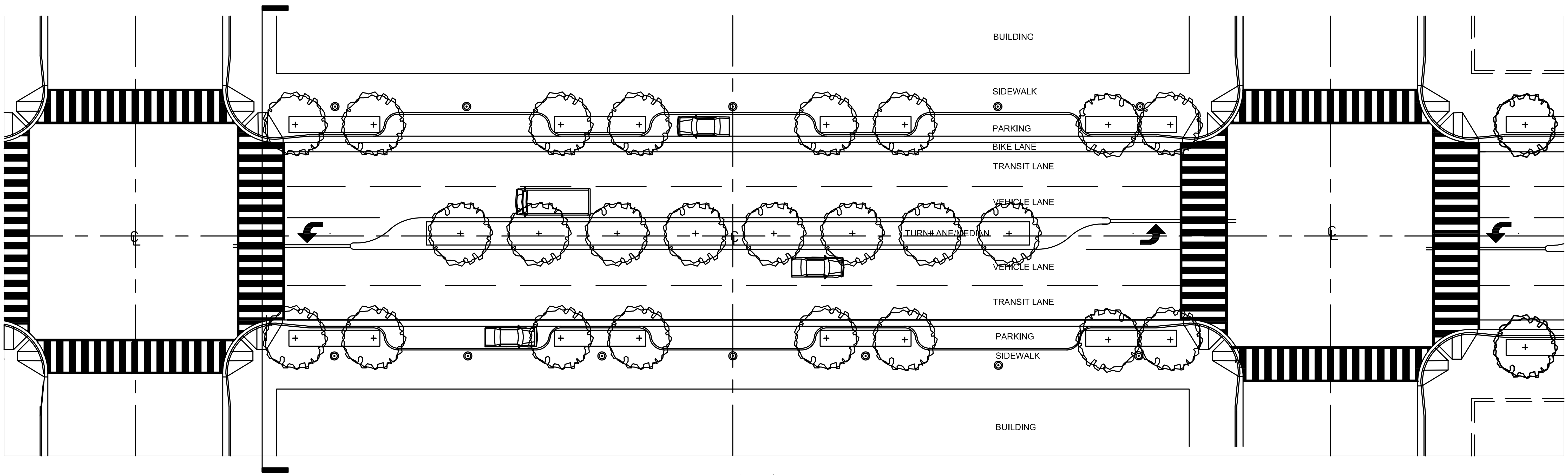
Notes

Bicycle lane on north side from S. Taylor St. to S. George Mason Dr. and on south side from S. George Mason Dr. to S.

Place bicycle lanes behind transit stops at locations where this will reduce the pedestrian crossing distance.

Special paving treatment in Village Center.

Section dimensions are shown at intersection. Mid-block has 2-foot gutter and 7-foot parking.



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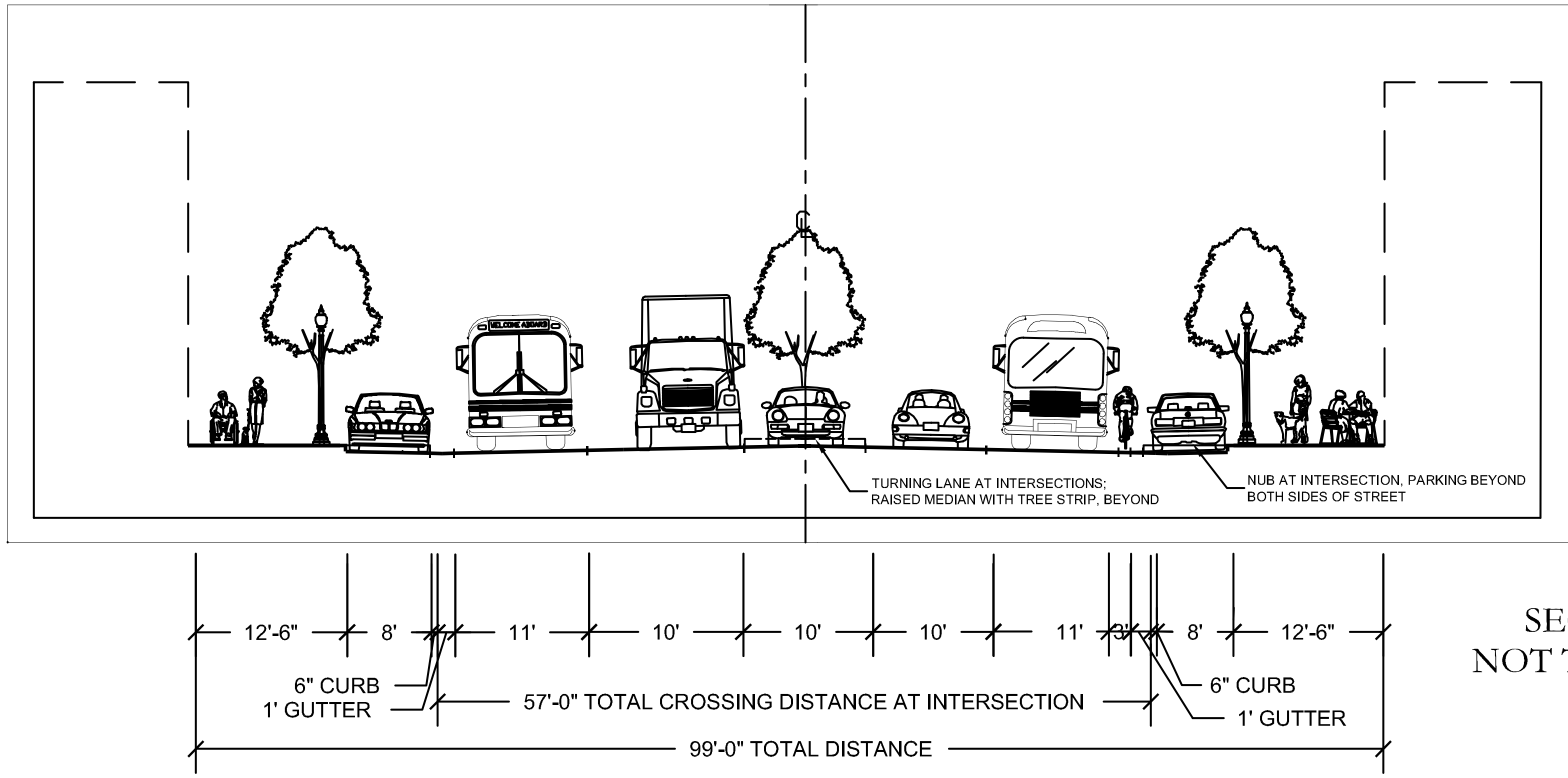


SECTION
NOT TO SCALE

Location

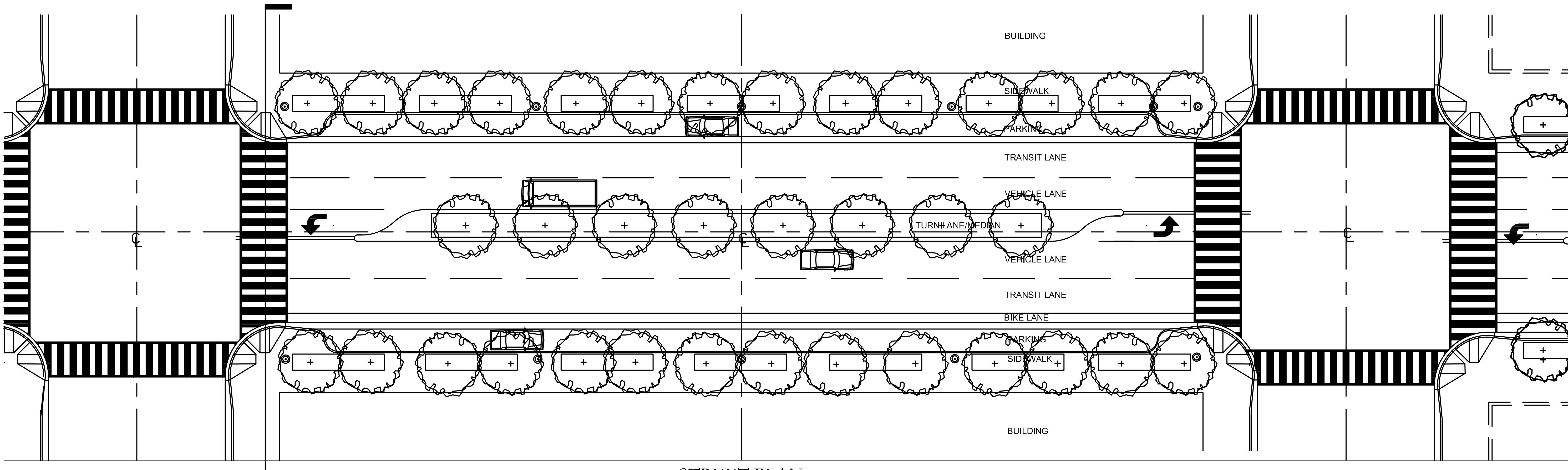
S. Randolph St. to S. Quincy St.

In Between
99' ROW

Notes

Bicycle lane on south side only.

Section dimensions are shown at intersection. Mid-block has 2-foot gutter and 7-foot parking.



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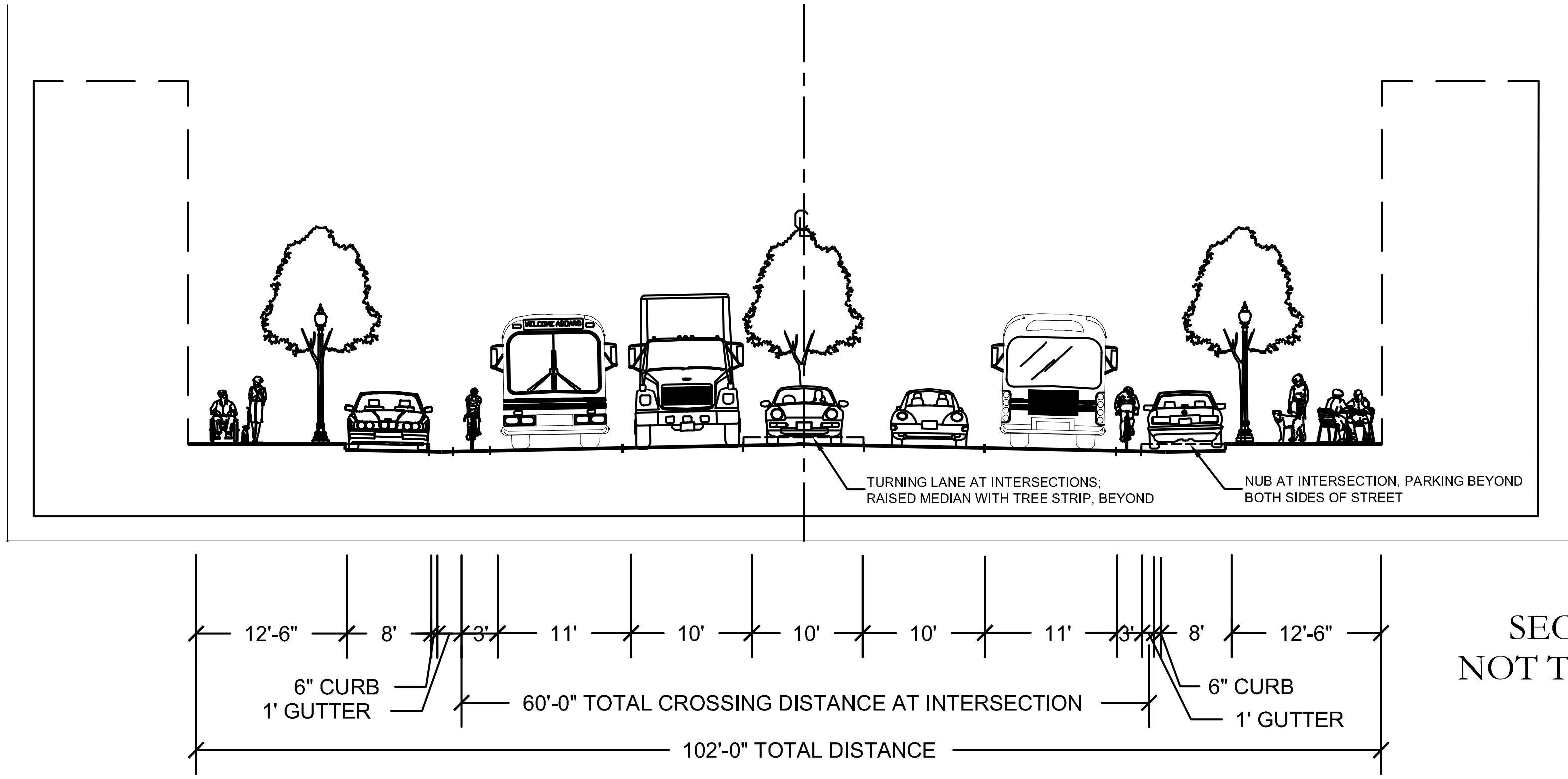

SECTION
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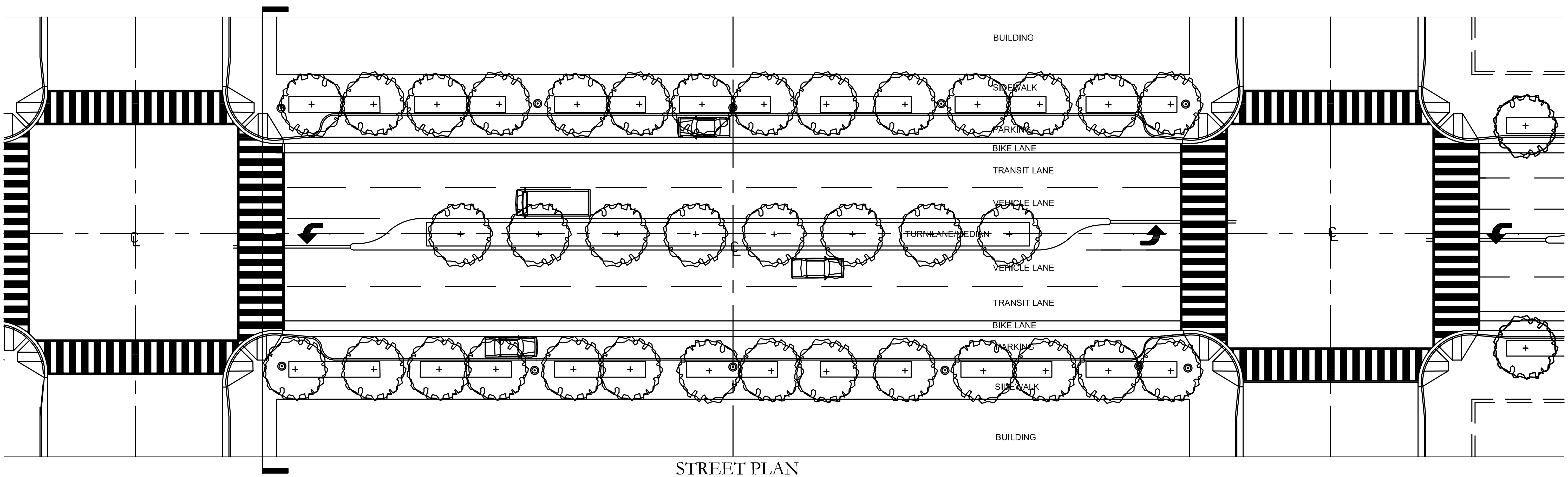
Location

S. Quincy St. to S. Oakland St.

In Between
102' ROW

Notes

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter and 7-foot parking.



STREET PLAN

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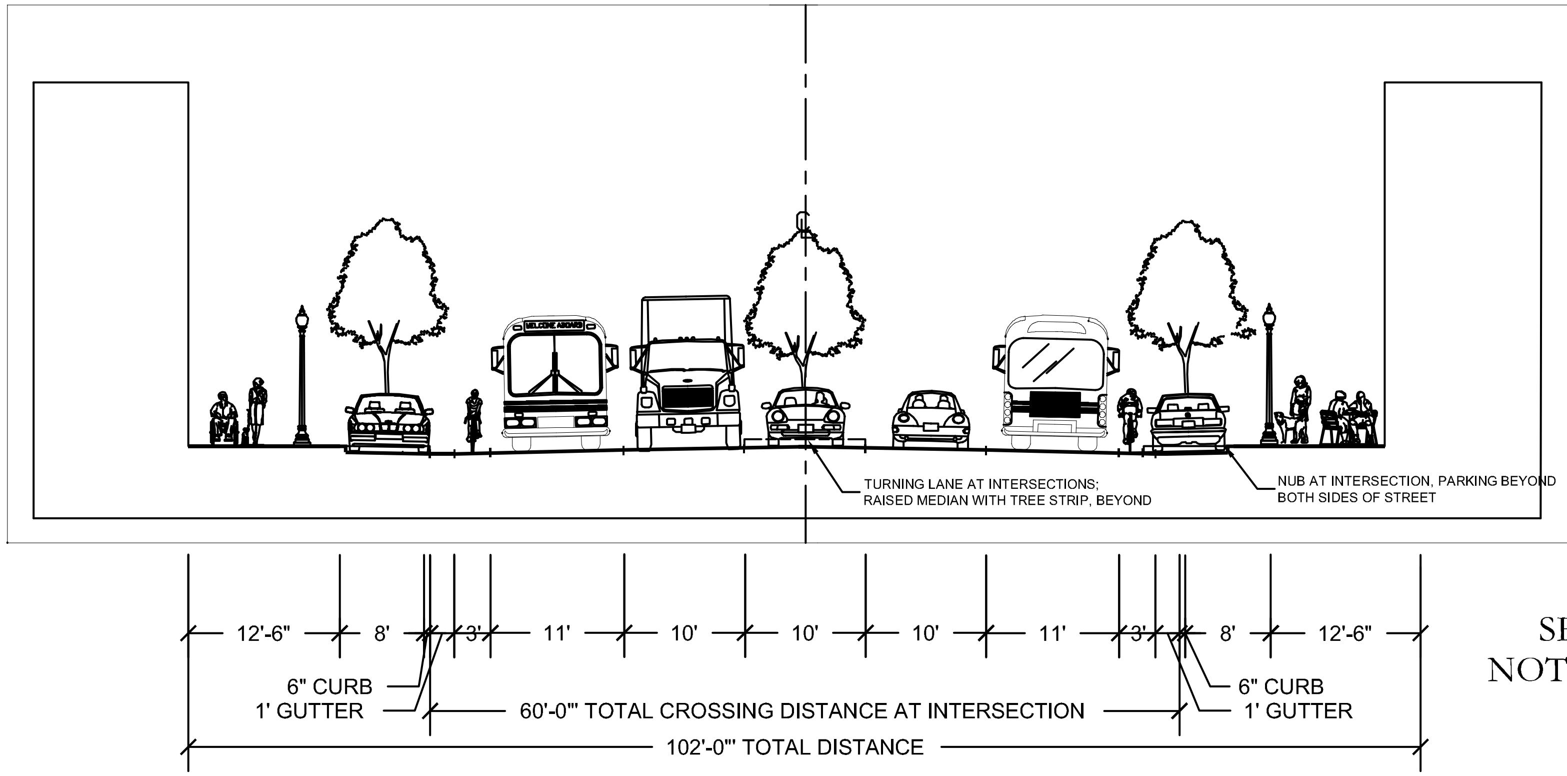

SECTION
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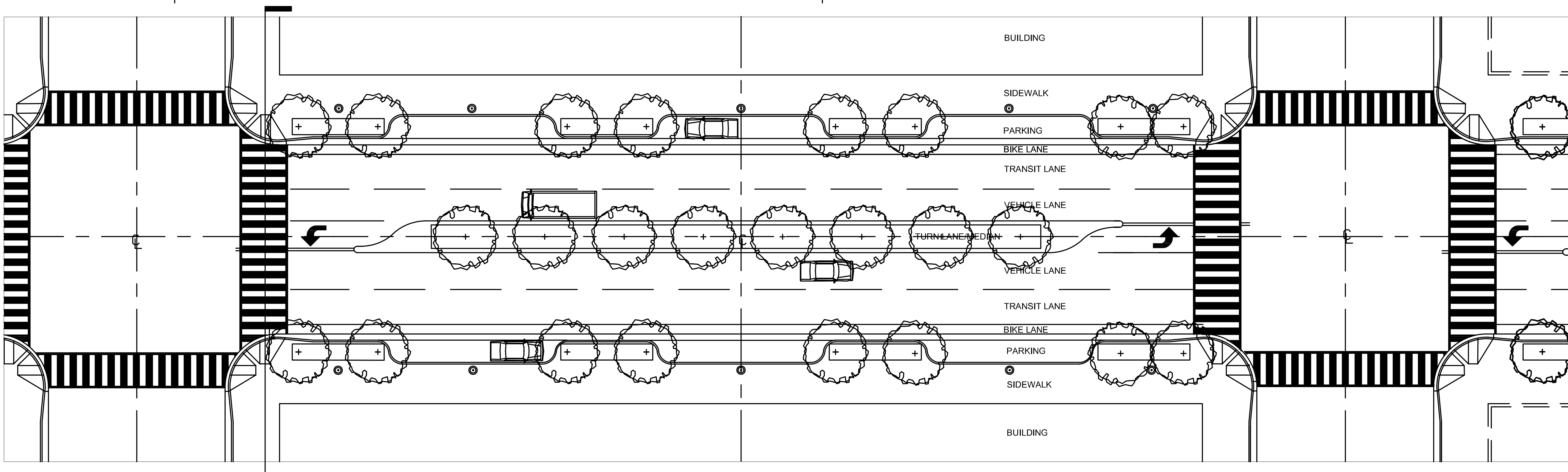
Location

S. Oakland St. to S. Highland St.

Town Center
102' RBL To RBL

Notes

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter and 7-foot parking.



STREET PLAN

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Columbia Pike

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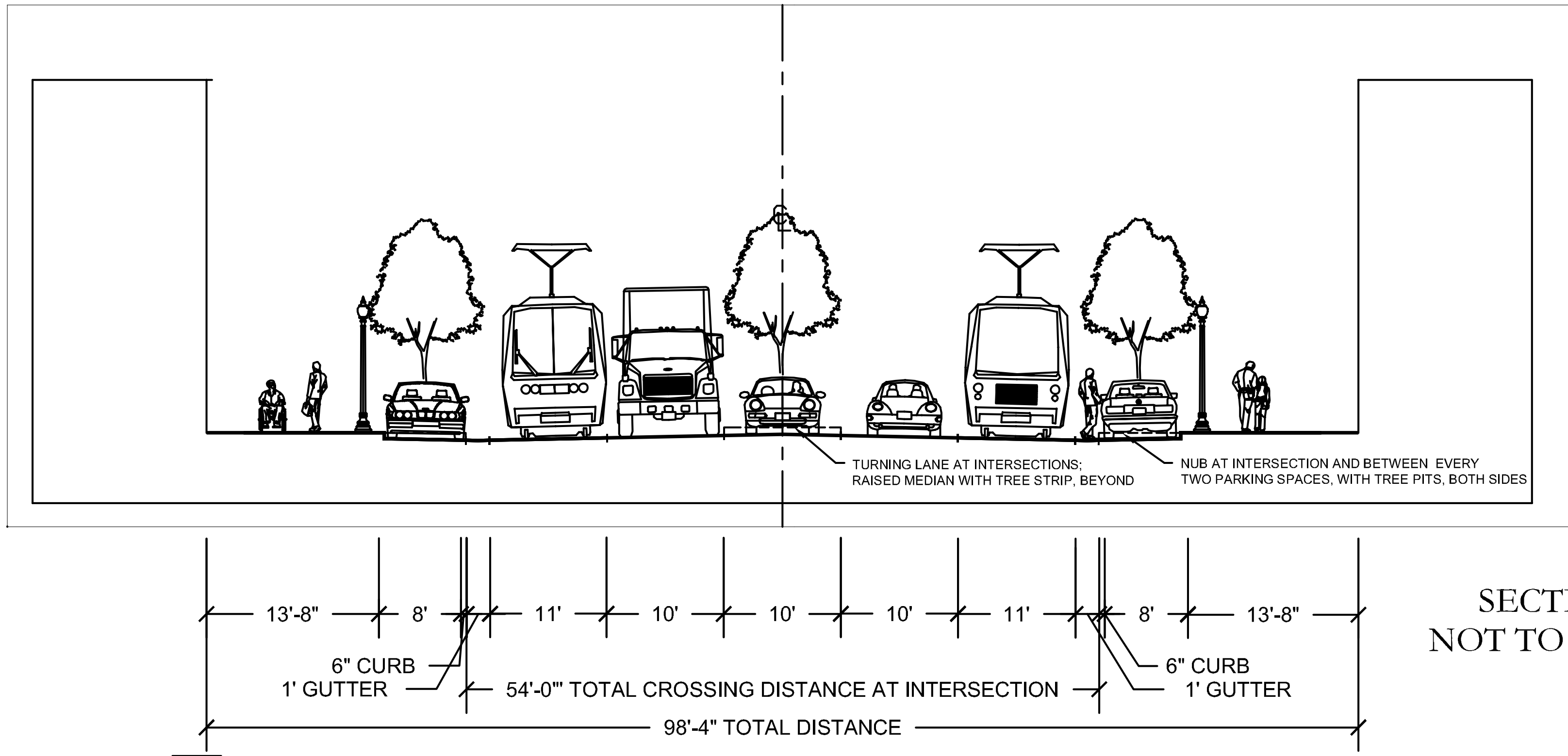

SECTION
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Location

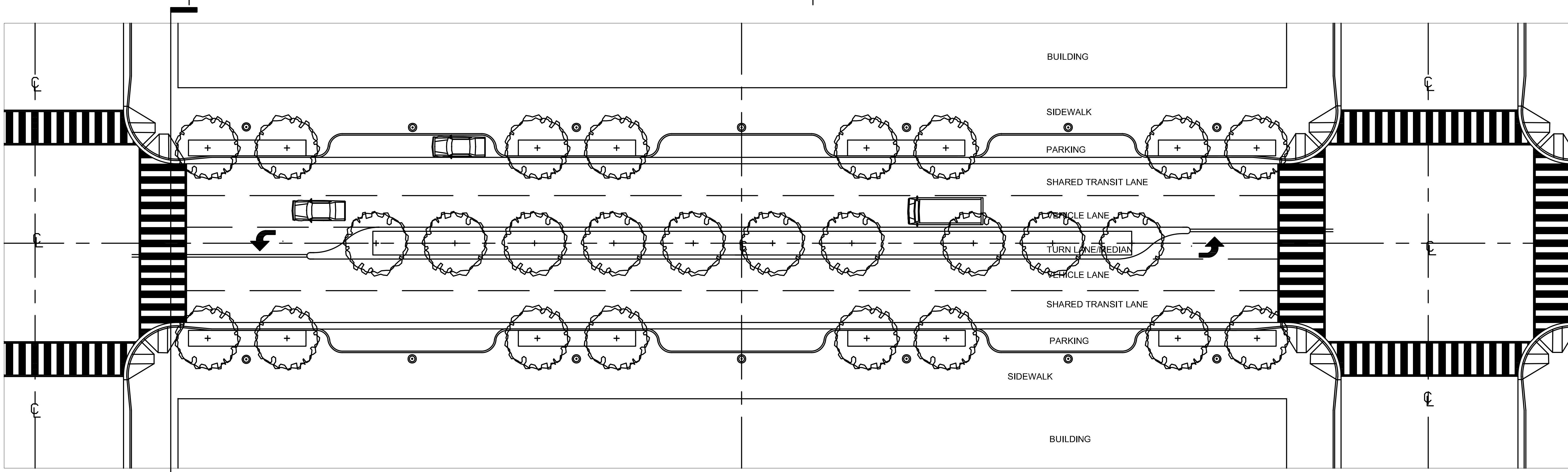
S. Highland St. to S. Walter Reed Dr.

Town Center
98'-4" RBL to RBL

Notes

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter and 7-foot parking.

Preserving historic buildings will reduce sidewalk width.



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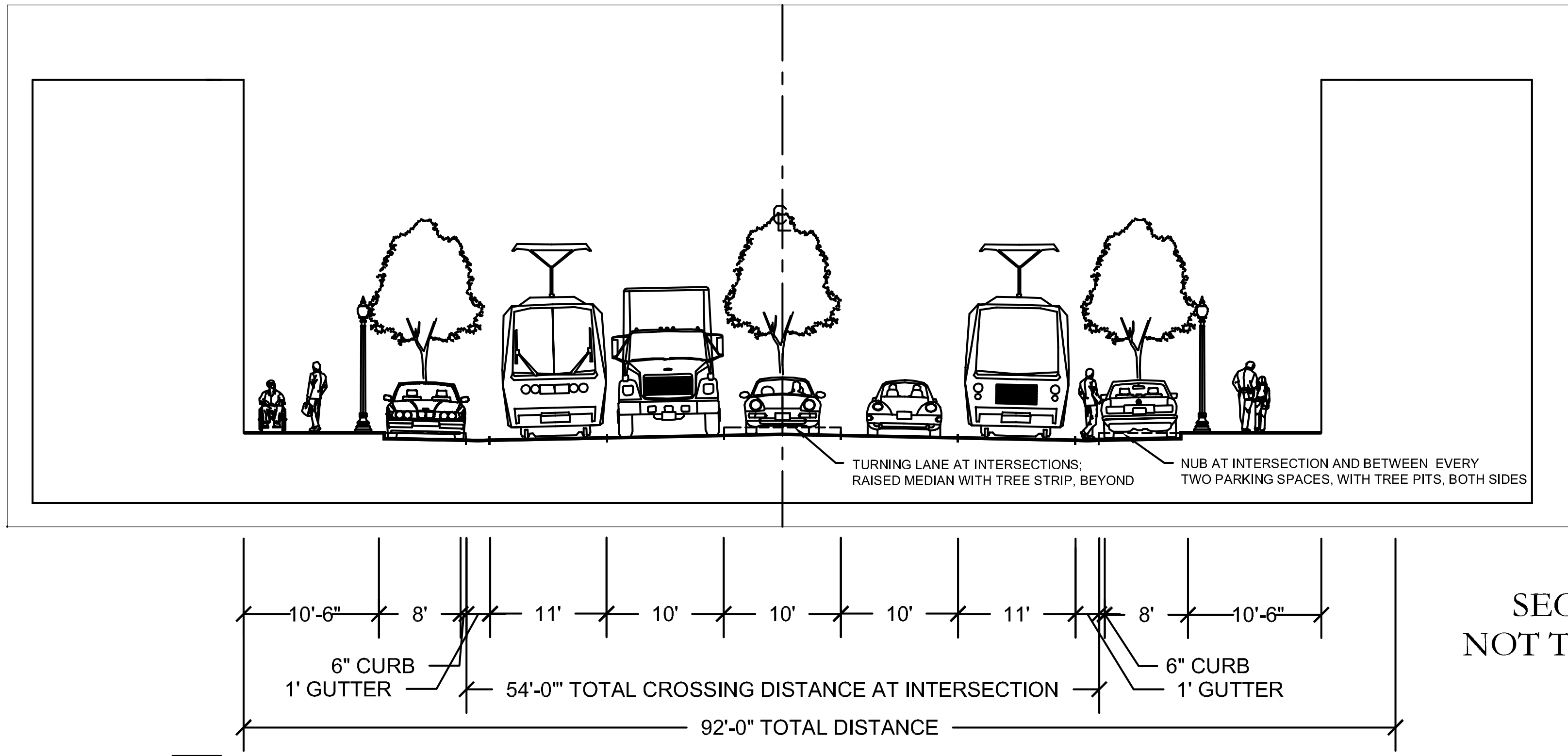

SECTION
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Location

S. Walter Reed Dr. to S. Cleveland St.

Town Center
92' RBL to RBL

Notes

Special pavement treatment at Civic Square.

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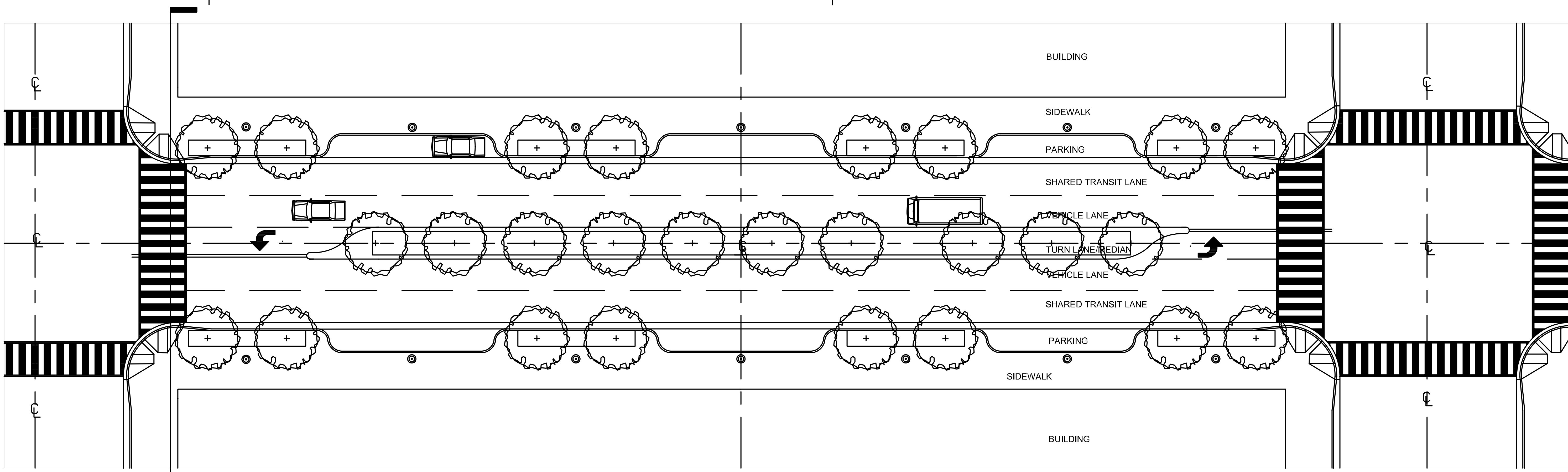
Mid-block has 2-foot gutter and 7-foot parking.

Preserving historic buildings will reduce sidewalk width.



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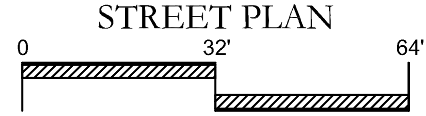

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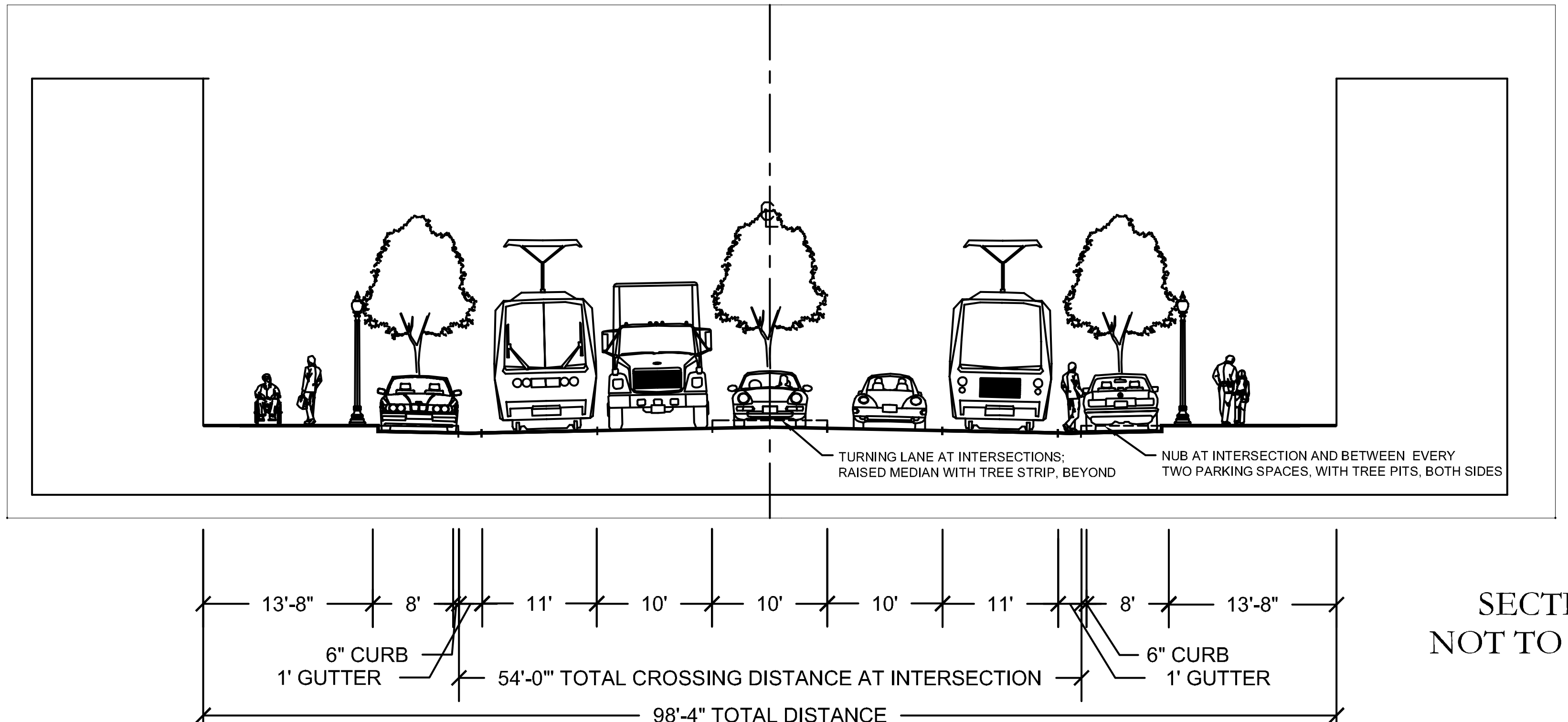

SECTION
NOT TO SCALE

Location

S. Cleveland St. to S. Wayne St.

Town Center
98'-4" RBL to RBL

Notes

Special paving treatment at Penrose Square.

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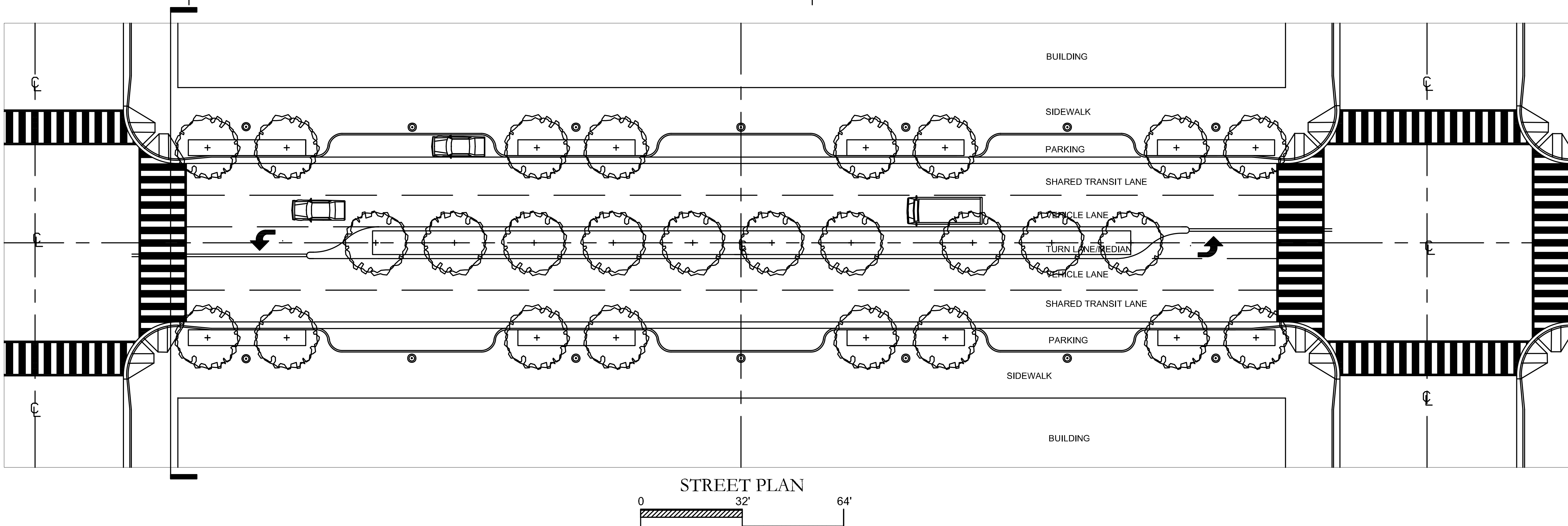
Mid-block has 2-foot gutter and 7-foot parking.



STREET PLAN

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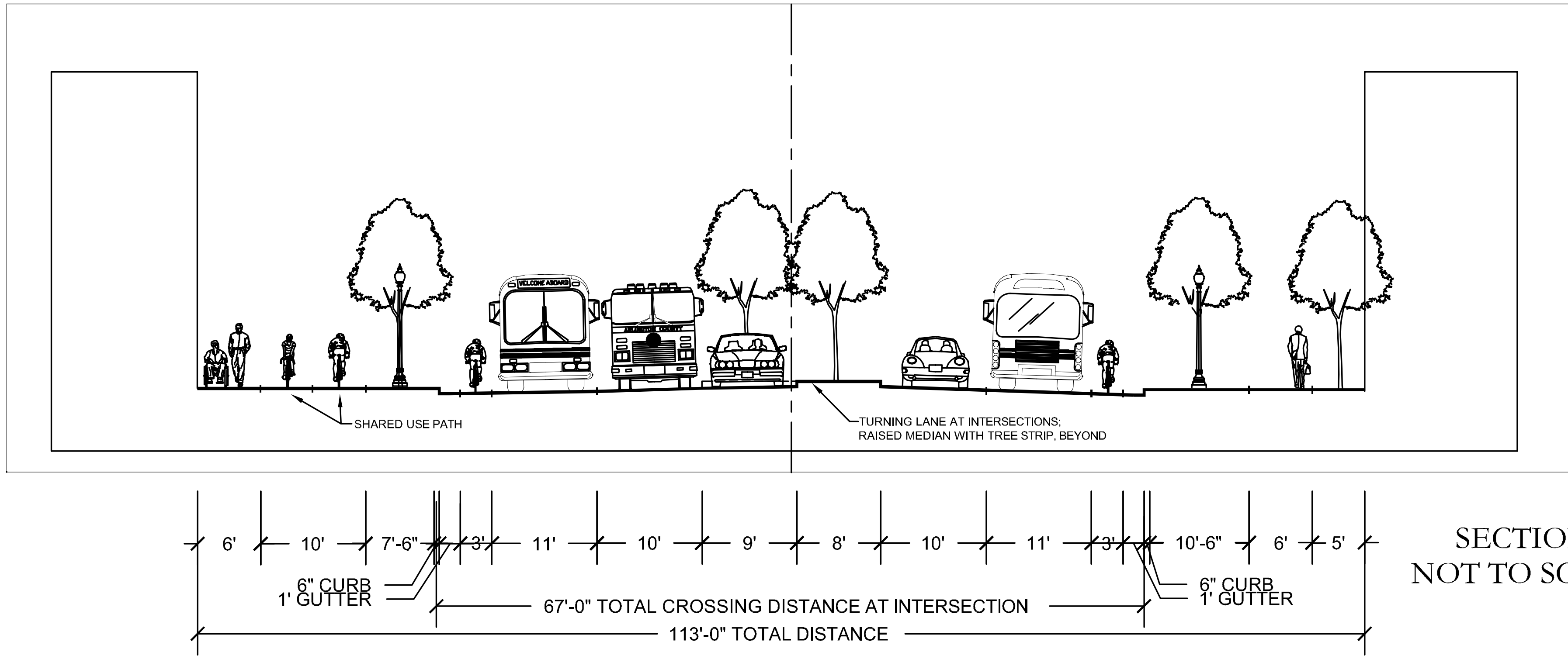


SECTION
NOT TO SCALE

Location

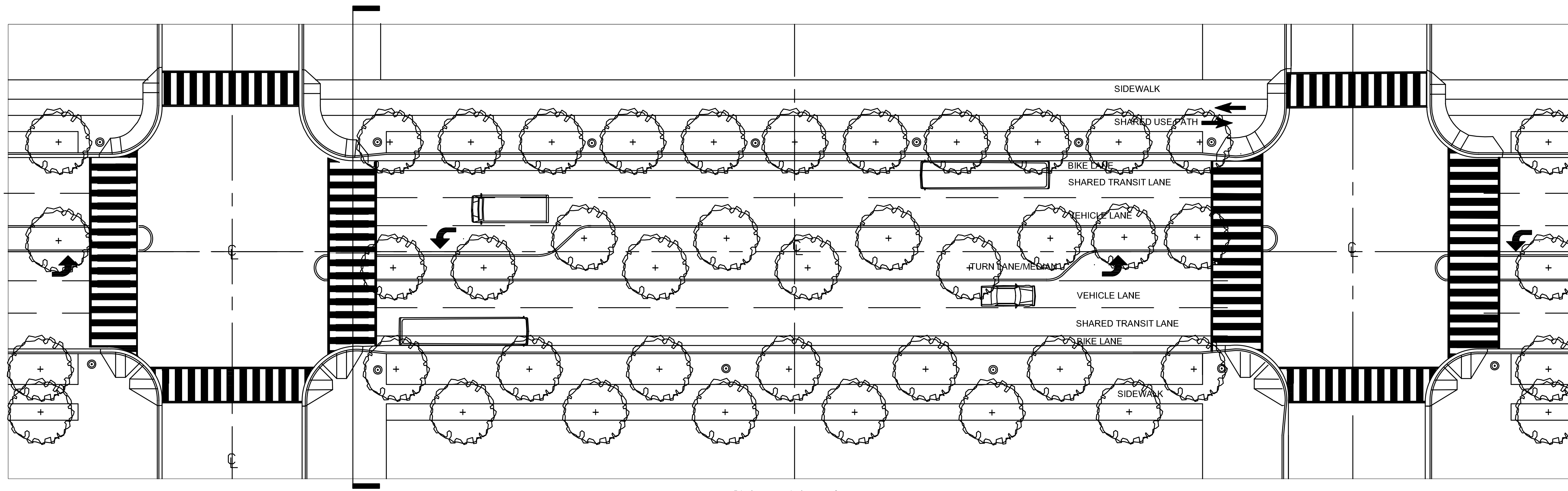
S. Wayne St. to S. Courthouse Rd.

Town Center
113' RBL to RBL

Notes

Shared use path on north side.

Section dimensions are shown at intersection. Mid-block has 2-foot gutter.



STREET PLAN
0 32' 64'

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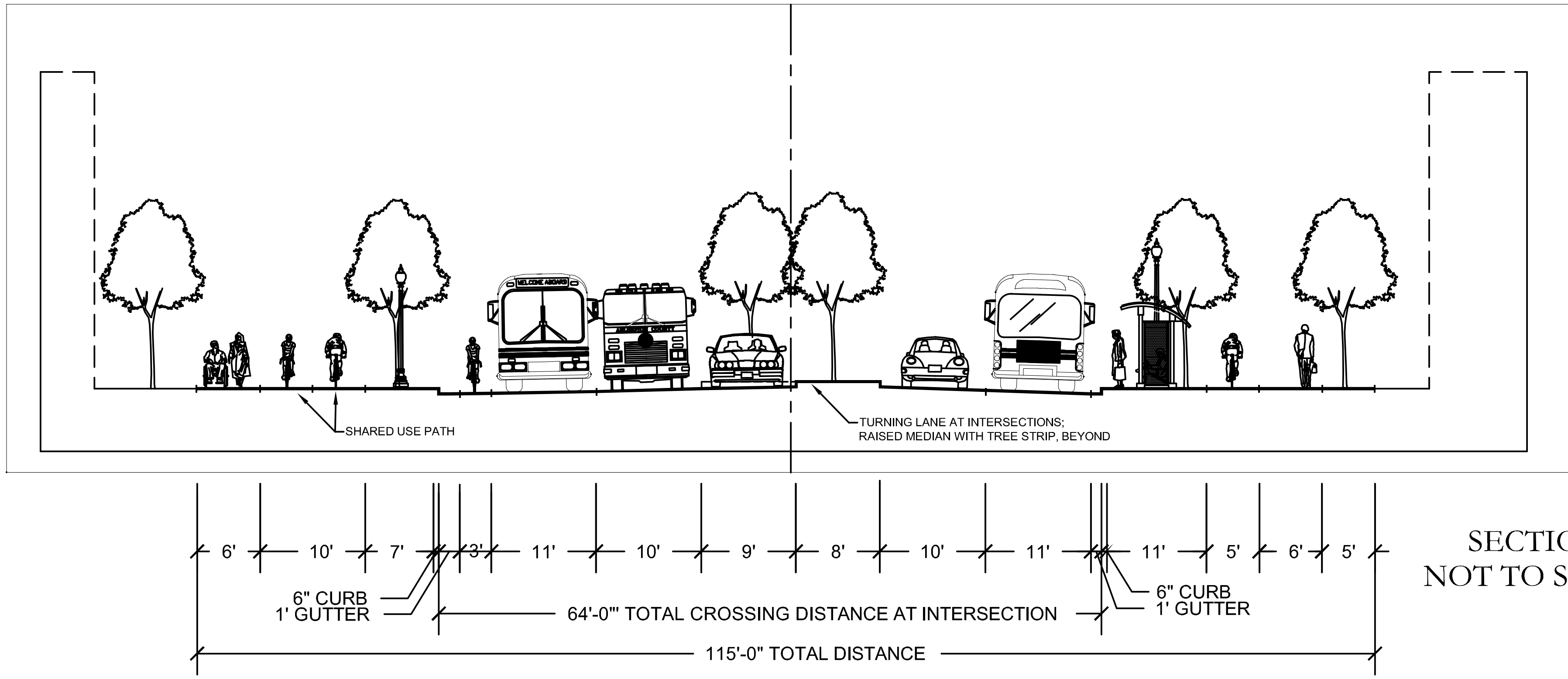


SECTION
NOT TO SCALE

Location

S. Courthouse Rd. to S. Scott St.

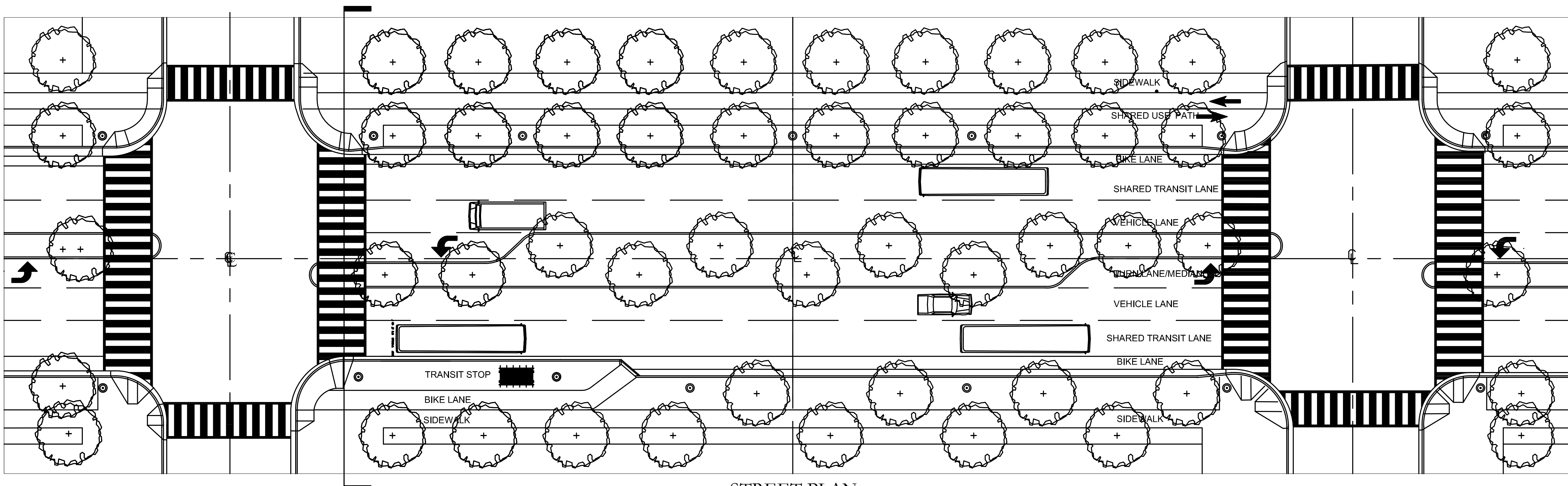
In Between
115' ROW

Notes

Shared use path on north side.

Place bicycle lanes behind transit stops at locations where this will reduce the pedestrian crossing distance.

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter.



STREET PLAN

0 32' 64'

Columbia Pike

Arlington County, Virginia

ARLINGTON
VIRGINIA

SECTION N

Department of
Environmental Services
Arlington County, Virginia

North

DATE:
06.29.05

PAGE:
N

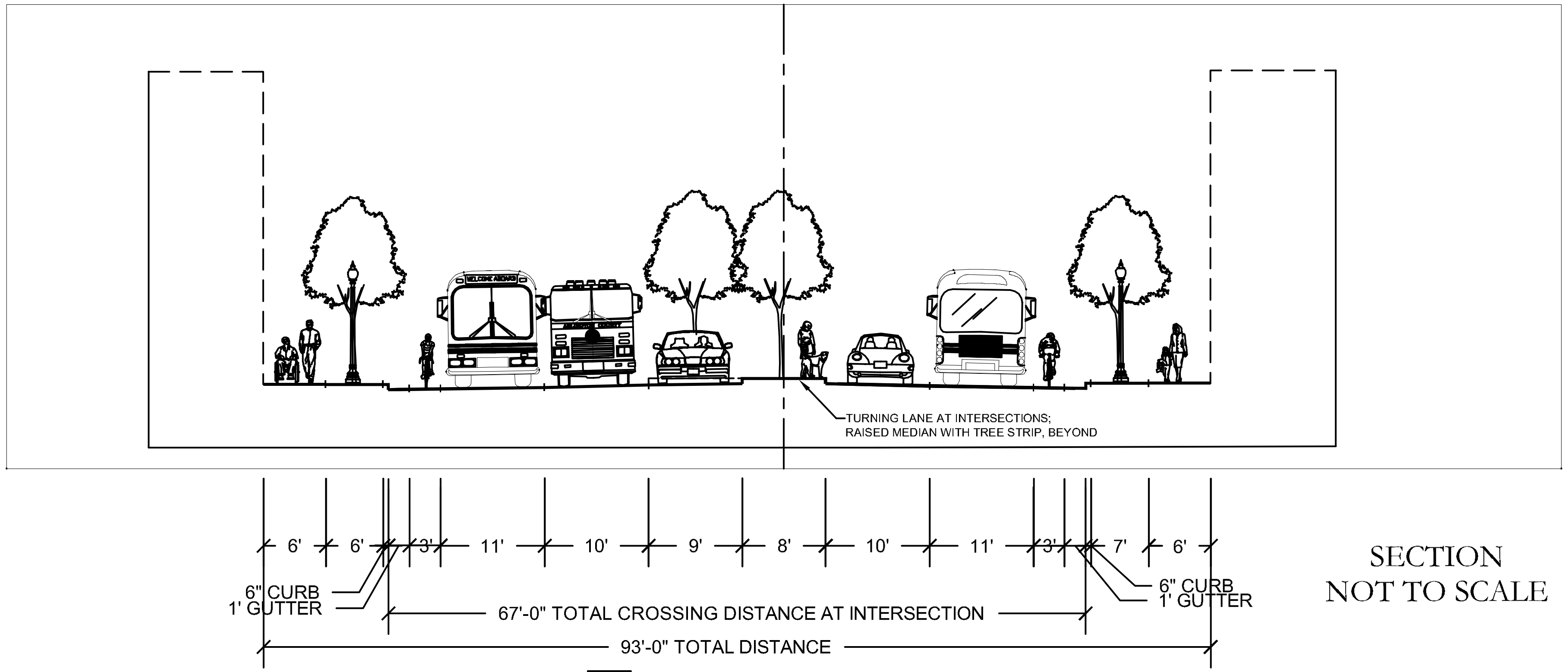
Location

S. Scott St. to S. Quinn St.

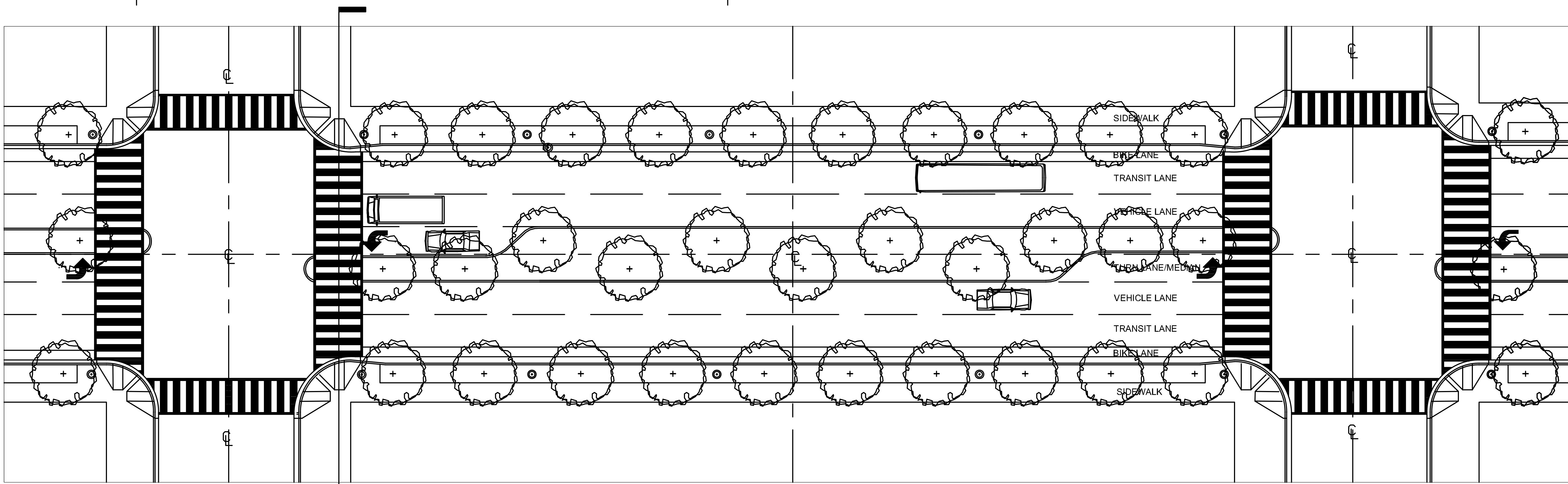
In Between
93' ROW

Notes

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter.



SECTION
NOT TO SCALE



STREET PLAN

0 32' 64'

Columbia Pike

Arlington County, Virginia

ARLINGTON
VIRGINIA

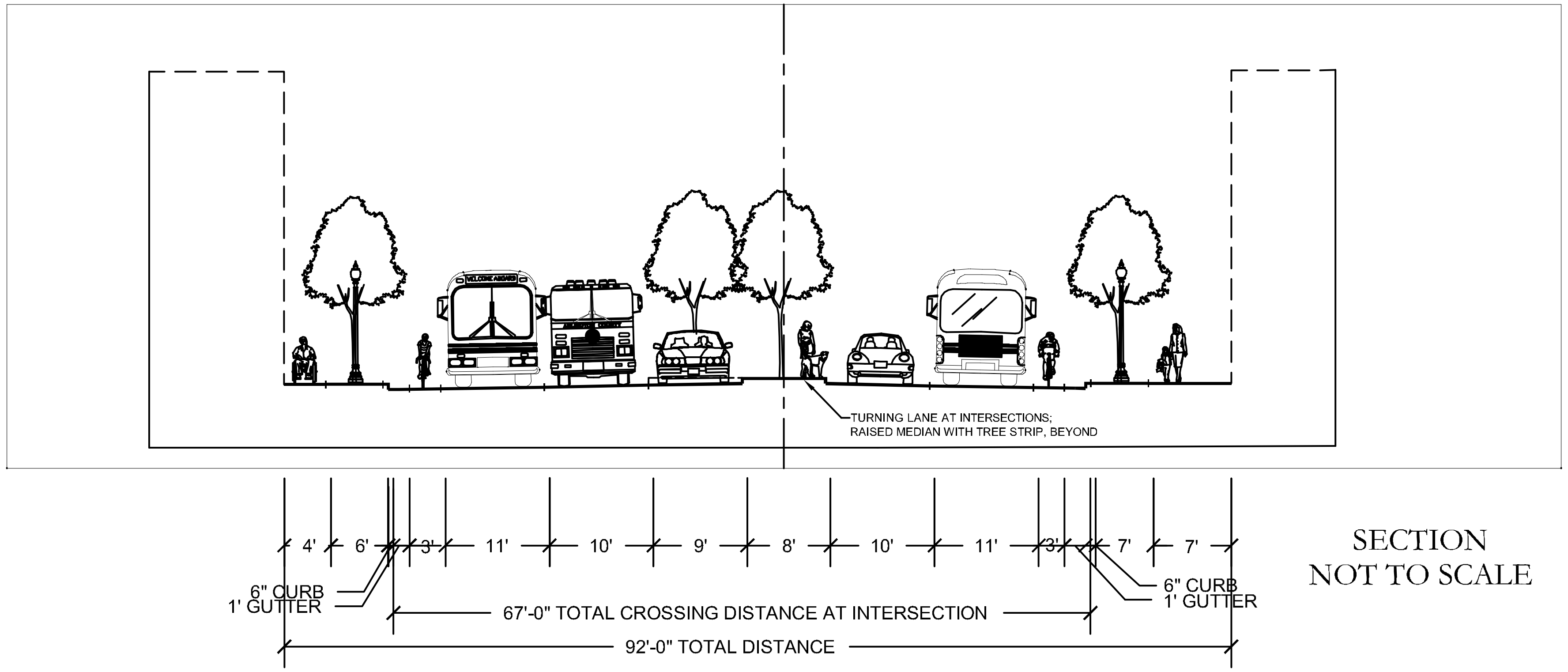
SECTION O

Department of
Environmental Services
Arlington County, Virginia

North

DATE:
06.29.05

PAGE:
O



SECTION
NOT TO SCALE

Location

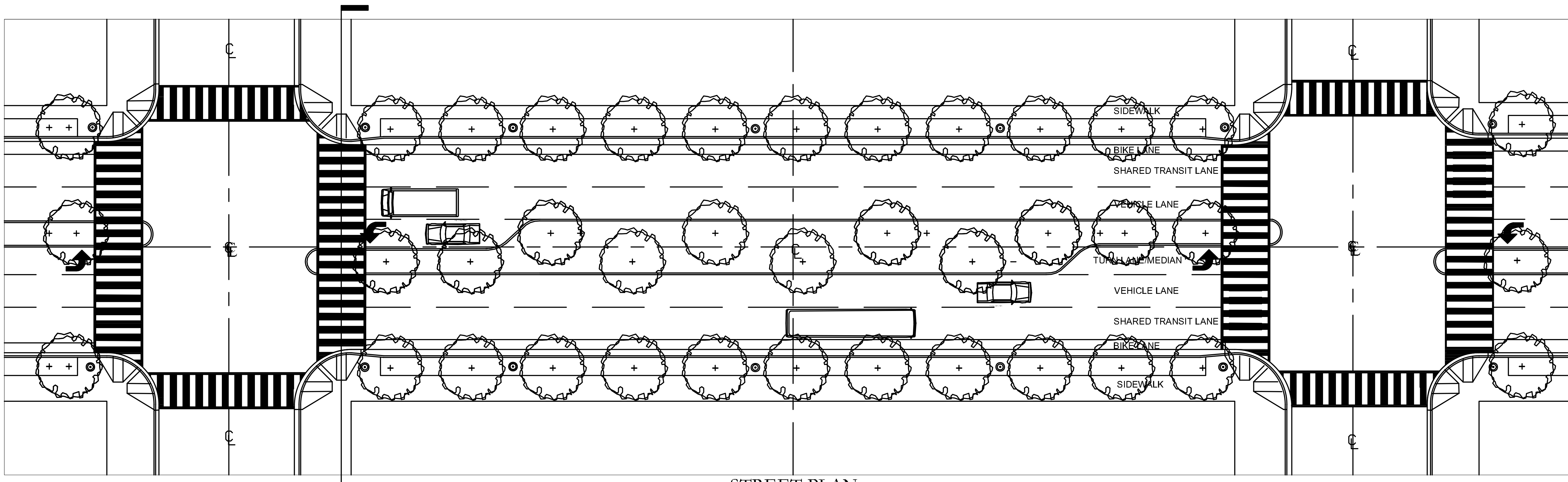
S. Quinn St.. to S. Orme St.

In Between
92' ROW

Notes

Design of roadway and sidewalks will be adjusted beneath Washington Boulevard Bridge.

Section dimensions are shown at intersection. Mid-block has 2-foot gutter.



STREET PLAN

0 32' 64'

Columbia Pike

Arlington County, Virginia

ARLINGTON
VIRGINIA

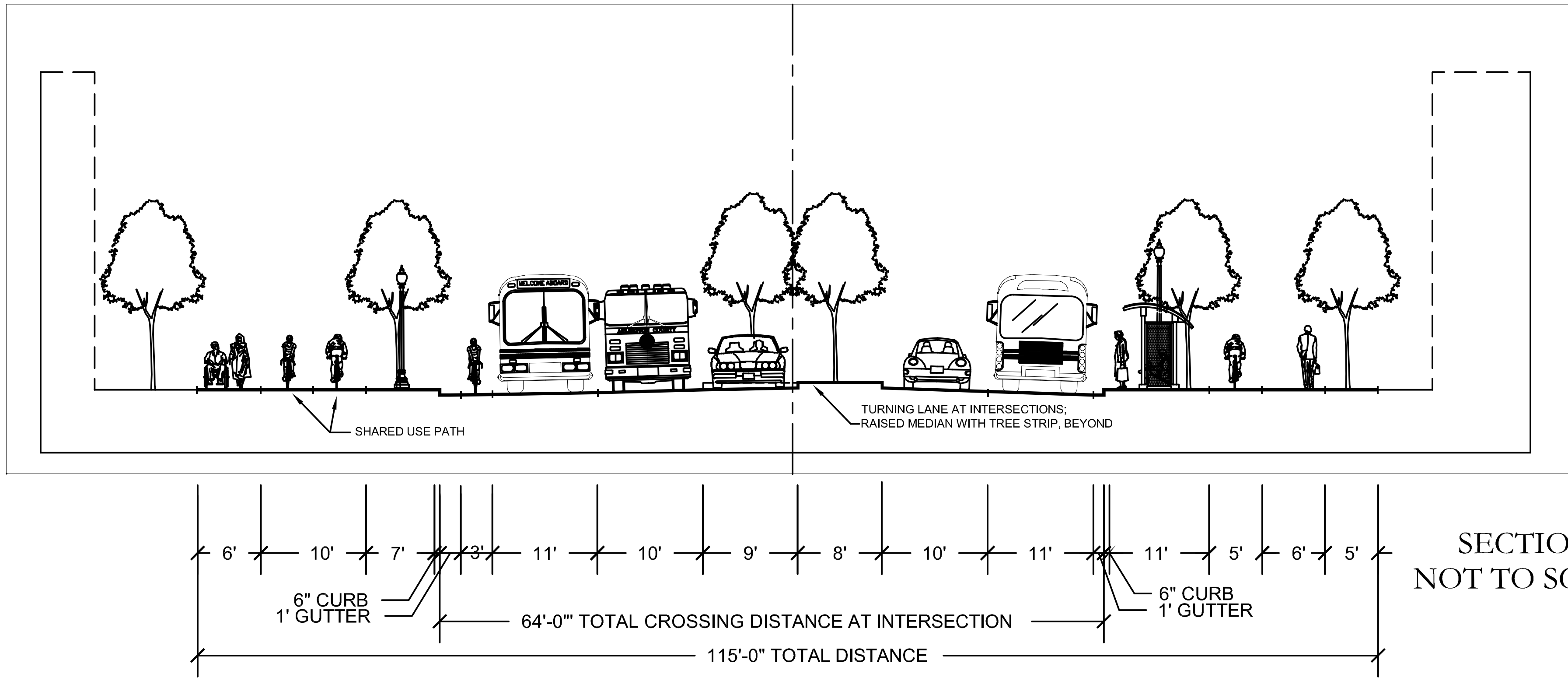
SECTION P

Department of
Environmental Services
Arlington County, Virginia

North

DATE:
06.29.05

PAGE:
P



SECTION
NOT TO SCALE

Location

S. Orme St. to S. Joyce St.

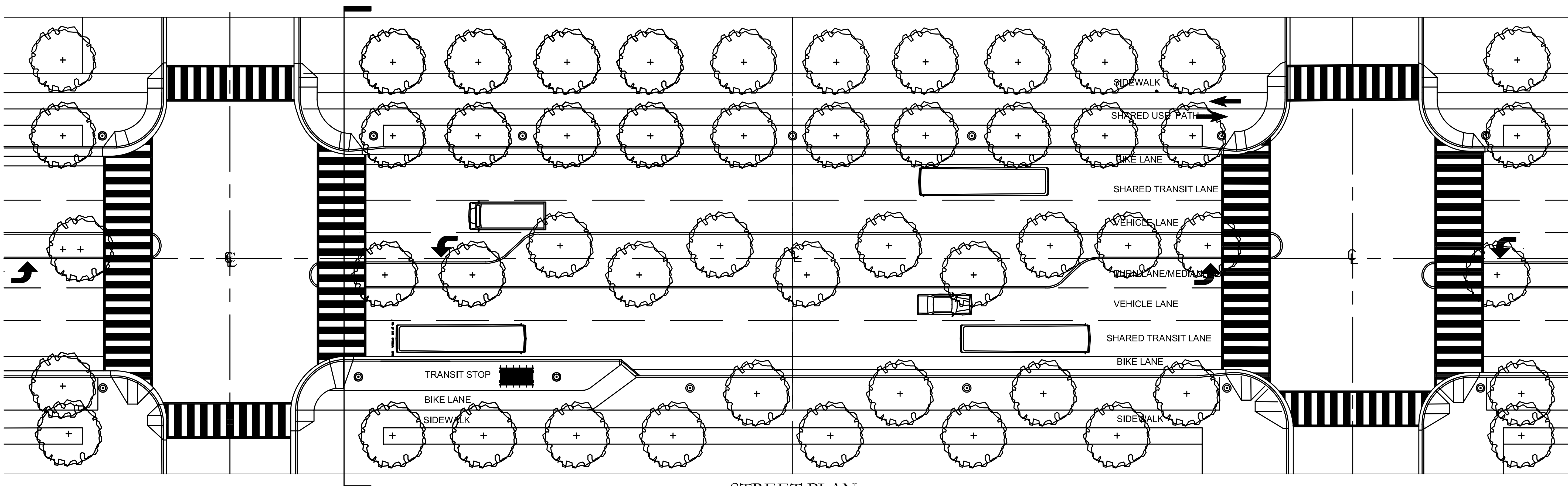
<u>In between</u>
115' ROW

Notes

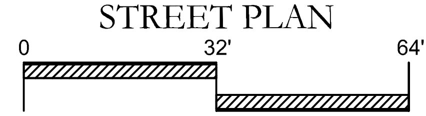
Shared use path on north side.

Place bicycle lanes behind transit stops at locations where this will reduce the pedestrian crossing distance.

Section dimensions are shown at intersection.
Mid-block has 2-foot gutter.



STREET PLAN



Columbia Pike

Arlington County, Virginia

ARLINGTON
VIRGINIA

SECTION Q

Department of
Environmental Services
Arlington County, Virginia

North

DATE:
06.29.05

PAGE:
Q

Relationship Between Lane Width and Speed

Review of Relevant Literature

Prepared for the Columbia Pike Street Space Planning Task Force
by the Parsons Transportation Group
September 2003

Summary

Many factors influence a driver's choice of speed on an individual street. In addition to lane width, these factors include roadway curvature, roadside development, type of traffic control, and many others. It is challenging to isolate the effect of lane width on speed. Two general methods to quantify this relationship appear in the literature:

- ***Before-and-after studies of a single roadway segment (case studies).*** When a roadway is restriped to provide narrower lanes, before-and-after speed results can imply a relationship between speed and lane width. This method is desirable because when a single site is evaluated, the effects of lane width can be more carefully isolated. However, this method has two disadvantages. First, all restriping projects change something in addition to lane width. Even if curb lines are not changed, narrower lanes allow surplus pavement to be occupied by another feature, such as left-turn bays, on-street parking, or bike lanes—changes in speed may be attributable as much to these features as to the narrowed lanes. Second, because this method reports results from only a single site, the results are entirely dependent on characteristics of that site, and they may not apply to other sites with different characteristics.

- ***Studies of several roadway segments of varying lane widths.*** With this method, a researcher can determine the differences in speed among a large number of roadway segments with different lane widths and derive a relationship between lane width and speed. An advantage of this method is that it uses a much larger sample size, so the results are more likely to apply elsewhere. However, there are inevitably differences between the sites studied other than lane width. Lane width may contribute to all of the observed speed differences, or it may contribute to very little. For example, a street in downtown Washington with 12-foot lanes will probably have *lower* speeds than a commuter route into the city with 10-foot lanes. Researchers must attempt to select sites that minimize this source of error.

There is no consensus in the literature on the relationship between lane width and speed. Some studies have shown speed reductions of as much as 3 mph for every foot of lane narrowing; other studies show a more slight speed reduction of about 1 mph per foot of lane narrowing or no significant effect at all. The studies generally agree that there is wide variability between sites, suggesting that lane width alone is not responsible for the entire speed reduction.

Several studies have reported the use of lanes 10 feet wide (or slightly narrower) with no perceived operational difficulties to buses and trucks. The following examples of narrow streets exist in Washington, D.C:

- 18th Street, NW, between E and K Streets, has average lane widths of 9.5 feet and carries 9 buses per hour during peak hours.
- Connecticut Avenue, NW, between the Taft Bridge and Chevy Chase Circle, has average lane widths of 10 feet and carries 11 buses per hour during peak hours.

Buses measure about 8.5 feet in width, and side-view mirrors extend about a foot on either side, making the mirror-to-mirror width about 10.5 feet. Passenger vehicles measure about 6 feet in width, while large trucks and SUVs are often about 7 feet wide. Side-view mirrors usually add between 6 and 12 inches to vehicles' total width.

Although 10-foot-wide lanes are generally acceptable in the literature, there is a strong preference to provide wider curb lanes to ease bus operation, separate traffic from roadside drainage and drainage features, and better accommodate on-street bicycles. Often, curb lanes are assumed to be 2 feet wider than interior lanes.

Lane width does not appear to be correlated to collision rate. Narrower lanes have been both credited for reductions in collisions and blamed for increases in collisions. In both cases, lane width alone is not the primary cause of changes in collision rate. For instance, narrowing lanes to provide left-turn bays is very likely to decrease collisions, but the drop in collisions can be nearly entirely attributed to the left-turn provisions.

Annotated Bibliography

Copies of the documents summarized below are available upon request.

Harwood, Douglas W., "Effective Utilization of Street Width on Urban Arterials," National Cooperative Highway Research Program Report 330, Transportation Research Board, August 1990.

- "Projects where narrower lanes were installed to provide space for installation of a center two-way left-turn lane generally reduce accidents by 24 to 53 percent. Projects where narrower lanes were installed to provide additional through traffic lanes on an arterial street generally did not affect midblock accident rates, but did increase accident rates at intersections."
- "Four percent of highway agencies have used 8 ft lanes on urban arterials, while 42 percent of agencies have used lanes of 9 ft or narrower, and 88 percent of agencies have used lanes of 10 ft or narrower."
- "More than 67 percent of highway agencies that have implemented narrower lanes reported no adverse traffic operational or safety problems. Other agencies reported some specific problems including: increases in sideswipe accidents; straddling of lane lines, particularly by trucks and buses; and turning problems at intersections, particularly for trucks and buses."
- Lanes narrower than 12 feet reduce the capacity of a roadway. Streets with 11' lanes have 3% less capacity than streets with 12' lanes. Likewise, streets with 10' lanes have 7% less capacity than streets with 12' lanes; streets with 9' lanes have 10% less capacity than streets with 12' lanes.

- "Field observations do not suggest a major safety problem related to narrower lanes. It may be that many of the unforced encroachments on adjacent lanes are made in situations in which the driver is aware that no conflicting vehicles are present."
- "Narrower lane widths (less than 11 ft) can be used effectively in urban arterial street improvement projects where the additional space provided can be used to relieve traffic congestion or address specific accident patterns. Narrower lanes may result in increases in some specific accident types, such as same-direction sideswipe collisions."
- "Projects involving narrower lanes nearly always reduce accident rates [in conjunction with] installation of a center TWLTL[1] or removal of curb parking. . . . Projects involving narrower lanes whose purpose is to reduce traffic congestion by providing additional through lanes may result in a net increase in accident rate, particularly for intersection accidents."
- "Lane widths as narrow as 10 ft are widely regarded by urban traffic engineers as being acceptable for use in urban arterial street improvement projects. . . . Lane widths less than 10 ft should be used cautiously and only in situations where it can be demonstrated that increases in accident rate are unlikely. For example, . . . this study found that 9- and 9.5-ft through-traffic lanes can be used effectively in projects to install a center TWLTL on existing four-lane undivided streets. On streets that cannot be widened, highway agencies should consider limiting the use of lane widths less than 10 ft (1) to project types where their own experience shows that they have been used effectively in the past, or (2) to locations where the agency can establish an evaluation or monitoring program for at least 2 years to identify and correct any safety problems that develop."
- "Curb lanes should be wider than other lanes by 1 ft to 2 ft to provide allowance for a gutter and for greater use of the curb lanes by trucks."
- "Narrow lane projects do not work well if the right lane provides a rough riding surface because of poor pavement condition or the presence of grates for drainage inlets. . . . Projects with narrower lanes may be most satisfactory at sites with curb inlets that do not have grates in the roadway."
- "Curb lane widths of at least 15 ft are desirable to accommodate shared operation of bicycles and motor vehicles. . . . Decisions concerning implementation of projects with narrower lanes should consider the volume of bicyclists using the roadway and the availability of other bicycle facilities in the same corridor."

"Guidelines for the Location and Design of Bus Stops," Transit Cooperative Research Program Report 19, Transportation Research Board, 1996.

- "A traffic lane used by buses should be no narrower than 12 feet in width because the maximum bus width (including mirrors) is about 10.5 feet. Desirable curb lane width (including the gutter) is 14 feet."

Fitzpatrick, Kay, et al, "Design Speed, Operating Speed, and Posted Speed Practices," National Cooperative Highway Research Program Project 15-18 draft final report, July 2002. Summary published in **Transportation Research Board Compendium of Technical Papers, 2003.**

- "Access density is the number of access points (driveways and intersections) per mile. . . . Higher speeds [are] associated with lower access densities."

[1] TWLTL = Two-way left-turn lane

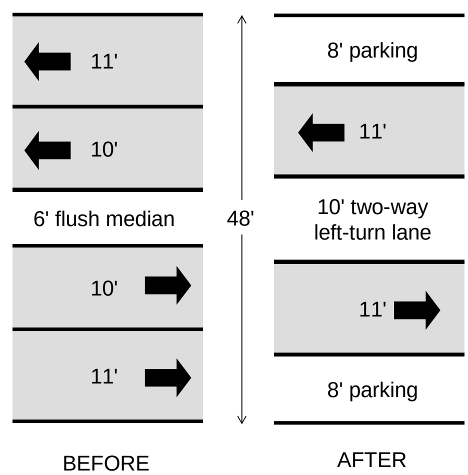
- "No relationship was apparent between lane width and speed."
- "While a relationship between operating speed and posted speed limit can be defined, a relationship of design speed to either operating speed or posted speed cannot be defined with the same level of confidence."
- "Design speed appears to have minimal impact on operating speeds unless a tight . . . curve is present."

Macbeth, Andrew G., "Calming Arterials in Toronto," Institute of Transportation Engineers Compendium of Technical Papers, 1998.

- "Toronto's arterial road traffic calming has relied on . . . a reduction in the number of traffic lanes. . . . On a four-lane street, drivers wishing to travel faster than others may simply change lanes to pass a slower vehicle. When a street has been narrowed to two lanes, . . . vehicle speeds are limited by the speed of the leading vehicle in a platoon."

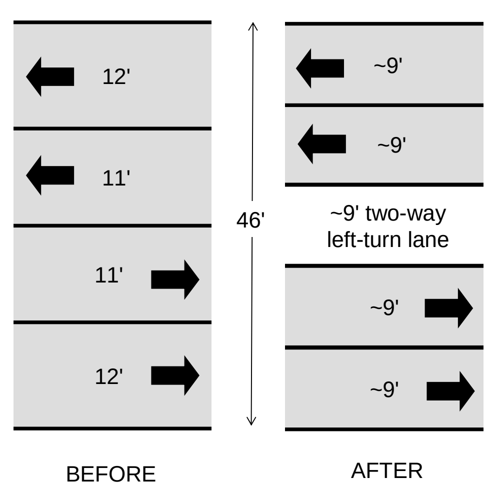
Skene, Michael, "'Traffic Calming' On Arterial Roadways?" Institute of Transportation Engineers Compendium of Technical Papers, 1999.

- "Most of the opposition [to traffic calming on arterial streets] . . . is from those who assume that traffic calming is a . . . movement to replace good engineering with bike lanes and slow inefficient traffic management schemes."
- Case study: Restriping of Cook Street corridor in Victoria, B.C., in November 1991. (See sketch at right.) The project's primary goal was reducing collisions, which were largely related to left-turning vehicles. Collisions dropped from 36 per year to 19 per year after the restriping. Average daily traffic is about 24,000 and dropped only slightly after restriping. Peak-hour volume dropped somewhat more; parallel arterial streets are available to accommodate traffic diversion. 85th percentile speeds were reduced from 32 mph to 29 mph, primarily due to loss of opportunities to pass slower-moving traffic.



Delabure, Brad; transportation planner, City of Victoria, B.C. Telephone conversation with R. Dittberner, September 22, 2003.

- Case study: Quadra Street corridor. As part of a landscaping and land-use revitalization project, the Quadra Street corridor was restriped from a 4-lane section to a 5-lane section with a two-way left-turn lane. (See sketch at right.) The goal of the project was providing a two-way left-turn lane without sacrificing capacity. Average speeds dropped from 30 mph to 25 mph, but much of the speed drop can be attributed to new landscaping (including street trees) and revitalized commercial development along the corridor. The street is a major transit route and houses several delivery-



intensive businesses, such as a furniture store. There have been only negligible operational problems with buses and trucks using the narrowed lanes.

West, James E., "Arterial Traffic Calming – Is It An Oxymoron?" Institute of Transportation Engineers Compendium of Technical Papers, 2000.

- "In Oregon, Special Transportation Areas (STA) have been designated in the Oregon Highway Plan. The STA designation is the state's way of formally recognizing certain sections of state highway as main streets, thus allowing the use of highway designs and mobility standards that are different from other highway designations, including the use of traffic calming features. An STA is intended to permit traffic movements along the main street to be balanced with the needs for local access and circulation."

Lum, Harry S., "The Use of Road Markings to Narrow Lanes for Controlling Speed in Residential Areas," *Public Roads* vol. 47 no.2, September 1983. Reprinted in ***ITE Journal*** **vol. 54, no. 6, June 1984.**

- "Pavement markings combined with raised pavement markers to create an impression of a narrower street have no effect on the mean speeds or the speed distributions of drivers on residential streets."

Martens, Marieke et al, "The Effects of Road Design on Speed Behaviour: A Literature Review," European Commission under the Transport RTD Programme, September 1997.

- "With decreased lane width, drivers show improved lane keeping, more accurate steering behaviour and a reduction in driving speed usually results. Yagar and Van Aerde (1983) found a reduction in speed of 1.1 mph for every foot of reduction in lane width beyond 13 feet." [Dimensions converted from metric.]
- "Both driving lanes and extra pavement strips on the left and right side of the road, for instance an emergency lane, contribute to the total amount of pavement width. This additional space [decreases] drivers' uncertainty, . . . something which usually leads to higher speeds. . . . The mean speed with a pavement width of approximately 20 feet is about 50 mph and with a width of 26 feet, the mean speed increases to about 55 to 60 mph." [Dimensions converted from metric.]
- "It is very difficult to measure the effect of pavement width itself, independently of other road design factors. This can probably explain the fact that the relationship between width of pavement and driving speed was established in some studies, . . . whereas in other cases no effects could be found."

Ewing, Reid, *Traffic Calming: State of the Practice,* Institute of Transportation Engineers, 1999.

- "Relative to wide streets, narrow streets may calm traffic. Vehicle operating speeds decline somewhat as individual lanes and street sections are narrowed (but only to a point). Drivers also seem to behave less aggressively on narrow streets, running fewer traffic signals, for example. Further, one study reports higher pedestrian volumes on narrow streets than on wide streets. . . .

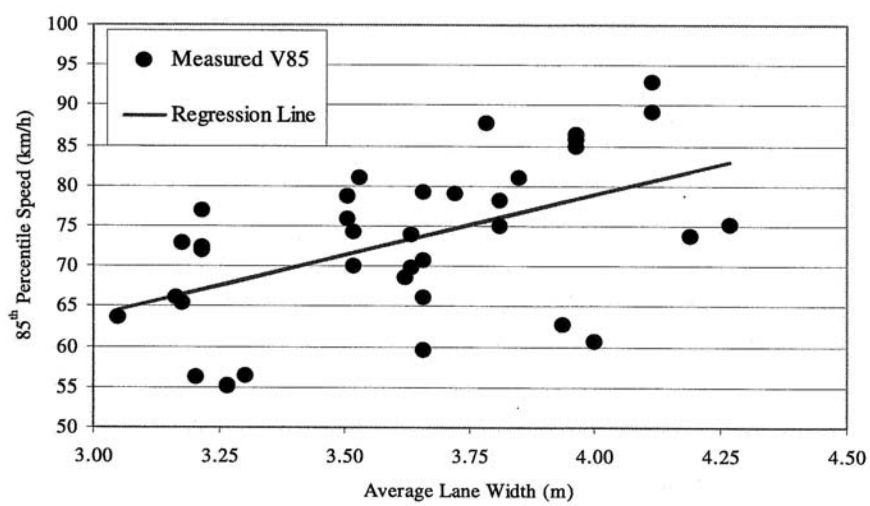
However, all other things being equal, bicyclists may prefer a wide street to a narrow street that has speeds 10 mph slower."

Heimbach, Clinton L. et al, "Some Partial Consequences of Reduced Traffic Lane Widths on Urban Arterials," Transportation Research Record 923, Transportation Research Board, 1983.

- Four-lane undivided urban roadways of various widths were analyzed to determine the effects of lane width on speeds and collisions.
- During off-peak hours, lane width correlates to speed at a rate of 0.6 mph per foot of lane width, as part of a multivariate expression with a correlation coefficient of 0.57. This suggests that narrowing lanes by one foot would tend to reduce speeds by 0.6 mph, when other factors are held constant.
- During peak traffic hours, the rate increases to 1.0 mph per foot of lane width, again as part of a multivariate expression, this time with a correlation coefficient of 0.53.
- Collisions increase as lanes are narrowed, but the relationship is not linear, so it cannot be expressed as a rate of collisions per foot of lane width. However, for typical values of other multivariate variables, narrowing lanes by one foot tends to increase collisions by 3 to 5 percent.

Fitzpatrick, Kay et al, "Design Factors That Affect Driver Speed on Suburban Arterials," Research Report 1769-3, Texas Transportation Institute, June 2000.

- On four-lane arterial streets, "speeds tend to be lower for narrower lanes. . . . When lane widths are 1 ft greater, [85th percentile] speeds are predicted to be 2.9 mph faster." [Dimensions converted from metric.] However, there is a substantial amount of site variability in the data, as illustrated by the plot at right.



- "The presence of a median (i.e., either a raised or a two-way left turn lane) indicated higher speeds than when no median was present." 85th percentile speed on streets without a median was about 38 mph, compared to speeds of 42 mph with a raised median and 44 mph with a two-way left-turn lane.
- Speeds decrease as the access density—number of intersecting driveways and intersections—increases. "The highest speeds for access densities above about 18 pts/mi are approximately 6 mph lower than the highest speeds for access densities below 18 pts/mi."
- In the studied data set, average speed was independent of signal spacing; however, signals in this study were relatively sparse, with an average of 2 signals per mile and never more than 4 signals per mile.

Columbia Pike Traffic Simulation
Technical Report

Prepared for the
Columbia Pike Street Space Planning Task Force

and
Arlington County, Virginia

Prepared by
PARSONS

November 2003

Background

Both the Washington Metropolitan Area Transit Authority (WMATA) and Arlington County have recognized the potential for transit improvements along Columbia Pike. Several studies are currently underway to determine the most appropriate characteristics of an improved transit system for the corridor.

In 2001, WMATA began its Columbia Pike/Leesburg Pike Transitway Study, which investigated routes for improved transit between Seven Corners in Fairfax County and the Pentagon in Arlington County. Phase 1 of this study compared several possible routes and proposed roadway cross-sections that would incorporate a transitway in the corridor. Phase 2 included detailed traffic simulation of several alternatives, ridership forecasts, and cost estimates. Phase 3 resulted in photo-renderings and animations of the options considered in Phase 2. Phase 4, scheduled to begin in late 2003, is a formal Alternatives Analysis and Environmental Assessment.

Meanwhile, Arlington County hosted the Columbia Pike Urban Design Charrette in fall 2002, renewing community interest in revitalizing Columbia Pike. Arlington County residents and staff considered transit as part of a larger plan to encourage redevelopment of the corridor. The redevelopment plan recommended specific street widths and detailed cross-sections, necessary to site new construction at the back of sidewalks.

In early 2003, the Arlington County board called for the formation of a citizens' task force to review the proposed street configurations in further detail. As such, the Columbia Pike Street Space Planning Task Force began meeting in April 2003, charged with developing cross-sections for Columbia Pike that would accommodate higher-capacity transit while encouraging the street's revitalization.

The Task Force reviewed the results of the traffic simulation that had been conducted as part of WMATA's Transitway Study. However, the Task Force requested that additional traffic simulation analysis be conducted for additional alternatives. The remainder of this report documents the results of traffic simulation conducted at the request of the Task Force.

Introduction

The alternatives considered as part of the Columbia Pike/Leesburg Pike Transitway Study, Phase 2, were the foundation for further traffic simulation efforts. The results of the study were presented in *Transit Study – Columbia Pike/Leesburg Pike, Phase 2 Report*, dated October 2002.

The study analyzed the effects of four key variables, and the following results were generated from the traffic simulation efforts:

- Two transitway routes, labeled Route A and Route B, were considered. However, both routes use the entire length of Columbia Pike in Arlington County, so the choice of a route does not impact Columbia Pike.
- Transitways were considered at both the curbside and the median. In general, the study found that a curbside transitway offers slightly better traffic and transit operations than a median transitway. When a transitway is in the median, conflicts arise between transit vehicles and left-turning automobiles. These conflicts prevent left turns from operating at the same time as transit vehicles, making the traffic signals less efficient and causing more delay to all traffic. The curbside transitway conflicts with right-turning traffic, but the impact to overall delay is much lower.
- Light Rail Transit (LRT) and Bus Rapid Transit (BRT) vehicle types were considered. The study found very little difference between the two technologies. BRT vehicles were modeled using LRT operating strategies, so the similarity in the results was not surprising.
- Impacts in the years 2010 and 2020 were considered. Because of the gradual increase in traffic over time, it is expected that conditions in 2020 would be slightly more congested than in 2010, regardless of the transitway configuration.

These primary conclusions derived from the Phase 2 study were based on the assumption that the transitway would largely operate in exclusive right-of-way, in a separate lane than automobile traffic. The only exception was a portion of the Arlington Town Center, between Highland and Cleveland Streets, where the transitway was assumed to operate mixed with traffic. However, no transit stations were located in this section, minimizing the impact of the shared-flow area.

The Columbia Pike Street Space Planning Task Force asked that additional simulation be conducted to revisit some assumptions made in the previous study. The Task Force selected six additional alternatives for further analysis:

- ***Curb Shared.*** Much like the configuration of existing bus service, a curbside-running transit system was assumed to operate mixed with traffic flow for the entire length of Columbia Pike, with no exclusive transit lanes.
- ***Median Shared.*** A median-running transitway was assumed to operate in mixed traffic for the entire length of Columbia Pike.
- ***Curb Varies.*** A curbside transitway was assumed to operate in mixed flow east of Taylor Street, with the same configuration as the Curb Shared. West of Taylor Street, the transitway was assumed to remain at the curbside, but in an exclusive transit lane added to the two automobile lanes in each direction.

- ***Median Varies.*** A median transitway was assumed to operate in mixed flow east of Taylor Street and in exclusive right-of-way west of Taylor Street, retaining two automobile lanes in each direction for the entire corridor.
- ***Curb Exclusive.*** An exclusive transitway was assumed to occupy the existing curb lane of traffic, forcing all automobile traffic to use a single lane.
- ***Median Exclusive.*** The exclusive transitway was assumed to occupy the left lane of the existing street, pushing all automobile traffic to the curb lane.

Factors Common to All Alternatives

The six alternatives have the following elements in common:

Transit Vehicle Type

Because the Phase 2 transit study did not show a significant difference between LRT and BRT vehicles, the Task Force elected to model only BRT vehicles, under the assumption that the results should apply to LRT vehicles as well. Although the traffic simulation did not examine both technologies, there are several key operational differences between LRT and BRT:

- LRT routes are restricted to areas where a transitway has been constructed, but BRT routes are not. BRT routes could allow transit vehicles to leave the transitway to serve outlying areas. (The Phase 2 transit study did not take advantage of this operational flexibility of BRT systems, one reason why differences between LRT and BRT were found to be minor.)
- An LRT system cannot begin operation until the transitway has been fully constructed, a lengthy and costly process. However, if desired, a BRT system could begin operation with relatively little construction, especially if the system is intended to operate in mixed traffic. The quality of the system could then be improved gradually, for example, by implementing signal priority for transit vehicles, consolidating stations, and providing additional passenger amenities at stations.
- In the event of a broken-down vehicle, illegally parked car, or other incident blocking the transitway, BRT vehicles can leave the transitway to get around the incident. LRT vehicles do not have this flexibility.
- The rails needed for an LRT system require bicyclists to exercise more caution than the smooth pavement of a BRT system. Of particular concern is the interaction between transit vehicles and bicycles when a curbside LRT system operates in mixed traffic. In this configuration, bicycles are best accommodated without bike lanes, because LRT rails would need to enter the bike lanes so LRT vehicles could stop adjacent to the curb.
- Despite BRT's operational flexibility, LRT systems are generally viewed more positively by the public. Slightly higher ridership would be expected on an LRT system when other factors are held constant.

Desired Speeds

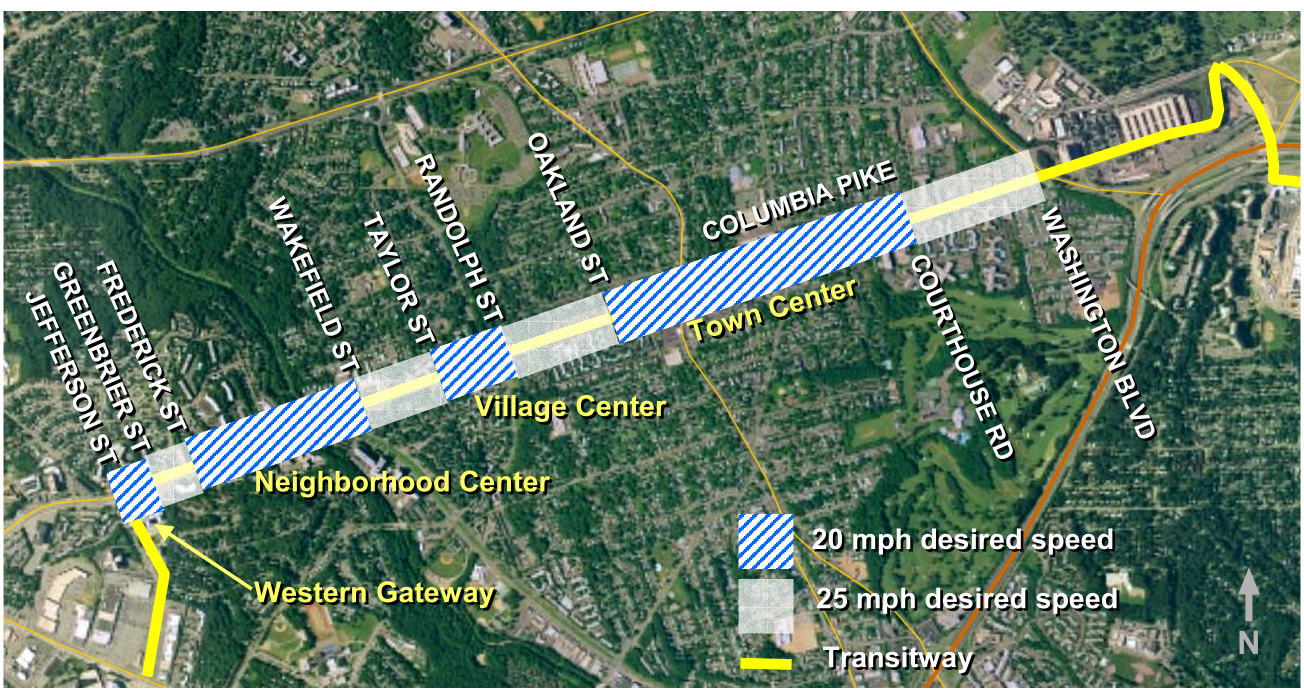
The Phase 2 transit study assumed that individual vehicles on Columbia Pike desire to travel at speeds in the range of 30 to 50 mph. The average desired speed of 40 mph is consistent with speed studies on Columbia Pike, which show 85th percentile speeds of about 40 mph.

Desired speeds in the current study were reduced significantly from the Phase 2 study. Vehicles in the four activity centers on Columbia Pike were assigned desired speeds averaging 20 mph, in a range varying from 17 to 23 mph. Between the activity centers, vehicles were assigned desired speeds averaging 25 mph, in a range varying from 22 to 28 mph.

Reducing the desired speeds implies that the roadway will be modified to encourage drivers to choose much slower speeds. Absent these modifications, actual desired speeds would be unlikely to change from existing conditions. This study does not suggest any means by which this speed reduction could be accomplished, nor does it forecast any specific speed reduction. Instead, the decision to use much lower speeds was made to determine how the system would function in the event that speed reduction did occur in the future.

Figure 1 graphically depicts the desired speeds used in this study. It is clear from the figure that desired speeds change frequently, especially in the western portion of Columbia Pike. It may be appropriate to set desired speed goals that do not require speed changes as frequently.

Figure 1
Distribution of Simulated Desired Speeds on Columbia Pike as Requested by the Task Force



Design Year

Design year 2020 was used in all alternatives modeled as part of the current study. The Phase 2 transit study documented that 2020 conditions are slightly and uniformly more congested than in 2010 regardless of the transitway alternative considered.

Assumptions From Previous Study

Several assumptions made in the Phase 2 transit study were carried forward to the current study. These assumptions include the following:

- Only the morning peak hour, 7:30 to 8:30 a.m., was evaluated. Traffic data suggest that the afternoon peak hour is at least as congested as the morning peak hour, with more vehicles entering and exiting Columbia Pike to patronize retail establishments that are not open early in the morning. A thorough review of afternoon peak hour conditions is recommended.
- Transit stations were consolidated and, in some cases, relocated. The target spacing for transit stations was between 1300 and 1800 feet, with closer spacing in denser areas. Many existing bus stops are closer than 1300 feet apart and were hence consolidated. In addition, it is desirable for transit stations to be on level sections of street, so new stations were positioned to avoid steep grades. All alternatives include the same number of transit stations at the same locations.
- Traffic volume was forecast according to growth projections developed by the Metropolitan Washington Council of Governments (MWCOG). Along Columbia Pike, the rate of increase was forecast at 0.9 percent per year between 2002 and 2010, and 0.8 percent per year between 2010 and 2020, compounded annually. Traffic volumes in 2020 were accordingly assumed to be uniformly higher than those in 2002 by 15.4 percent.
- The traffic volume forecast did not account for new development along Columbia Pike encouraged by the revitalization efforts. Redevelopment of Columbia Pike may result in a higher traffic growth rate than projected by MWCOG; if so, the number of automobile trips would likely be larger than predicted, causing travel times and delays to be longer than those included in this report. However, any such increases would apply to all alternatives.
- The increase in traffic volume by the year 2020 resulted in very poor conditions at the intersection of Columbia Pike and George Mason Drive; specifically, the intersection was unable to process the volume of traffic that was forecast to pass through. This condition caused extensive queues to propagate on approach to the intersection, and did not allow effective comparison of the remainder of the network. Instead, it was assumed that George Mason Drive would be widened from two to three through lanes in each direction. No change in lane configuration was assumed on Columbia Pike itself.

VISSIM Modeling

The simulation modeling was conducted with VISSIM, an advanced microscopic traffic simulation software package. Using VISSIM, a virtual model of the street network in the vicinity of Columbia Pike was created. Elements such as traffic signal control, lane configuration, and traffic volume were replicated in the model as closely as possible to field conditions. The model was then calibrated, ensuring that vehicle speeds, queues, and travel times in the model sufficiently matched data collected from the field.

Not all intersections were included in the model, but all signalized intersections and major unsignalized intersections were included. In some alternatives, traffic signals were added or removed at certain locations, but the intersections remain in the models of all alternatives to allow effective comparison.

The simulation models do not include pedestrian traffic; however, the models' traffic signals are designed to provide sufficient time for pedestrians crossing streets.

The Columbia Pike corridor uses a sophisticated traffic signal control system known as SCOOT (Split-Cycle Offset Optimization Technique). This system adjusts the timing of traffic signals in the corridor in real time to minimize overall delay to vehicles. The SCOOT algorithm is complex and proprietary, and it was not feasible to incorporate the system into the models. Instead, traffic signals were modeled with standard actuated-coordinated controllers running fixed cycle lengths. The cycle lengths used in the models were selected based on typical cycle lengths selected by SCOOT during the morning peak hour. However, the SCOOT system is likely to provide slightly better traffic service than the fixed-cycle system, so the results from the models would tend to be slightly worse than in the field.

In all six alternatives, the signal system was modified to allow signal priority for transit vehicles, allowing quicker transit travel. The traffic signal controllers were modified to make them aware of the locations of nearby transit vehicles. The signals offer priority to transit vehicles in two ways:

- If a transit vehicle arrives when a signal is green, but about to turn red, the traffic signal controller will hold the green light long enough for the transit vehicle to pass through.
- If a transit vehicle arrives when a signal is red, the signal controller will give the transit vehicle a green light as quickly as possible by reducing the amount of green time for cross traffic.

Transit vehicle signal priority can result in substantial improvements in transit vehicle operation, but these improvements are usually partially offset by a slight degradation in automobile traffic operations, often more pronounced on the cross street.

A typical roadway network operates predictably most of the time, but occasionally, unpredictable events occur. Lanes can be blocked by delivery trucks or parked or broken-down vehicles. Emergency vehicles can disrupt traffic flow. Collisions on a parallel route can divert excess traffic through the corridor. The models do not account for unusual non-recurring events of this type.

Description of Alternatives

Curb Shared

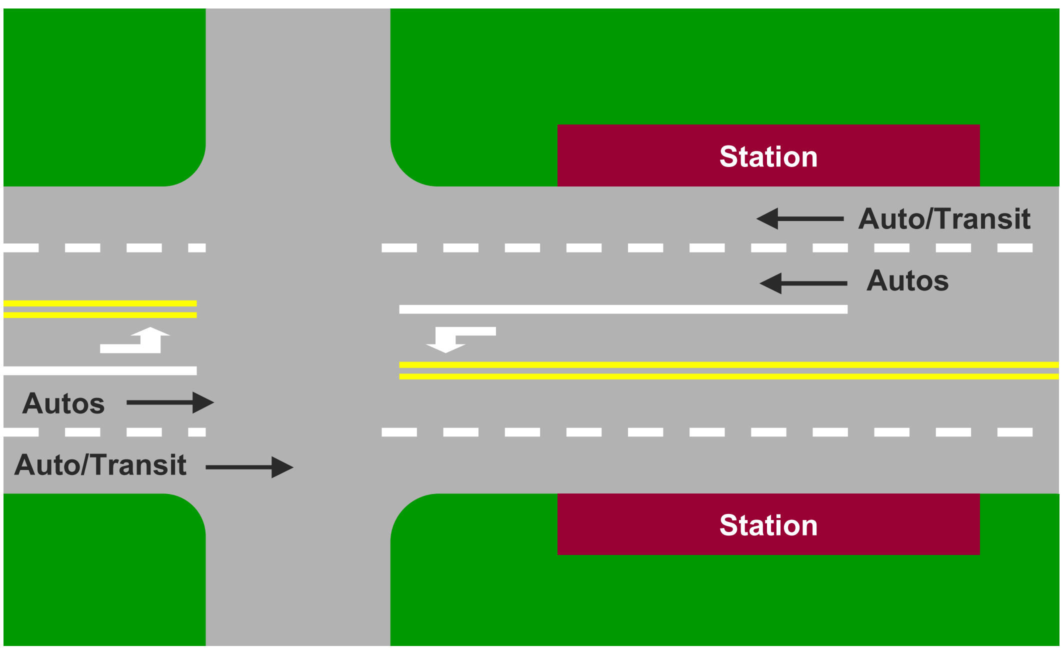
In the Curb Shared alternative, transit vehicles would operate mixed with automobile traffic on Columbia Pike from Jefferson Street to Washington Boulevard, much like the operation of existing bus service. This study only focused on the area between Jefferson and Washington, but it used the VISSIM models from the earlier Phase 2 transit study, which included the entire corridor from Seven Corners to Pentagon City. The transitway outside the limits of the current study area retained the same characteristics as in the earlier study, namely, an exclusive curbside transitway adjacent to two automobile lanes in each direction. However, the effects of the exclusive transitway are not reported in this document, because it only occurs outside the Jefferson-to-Washington study area. Figure 2 depicts the location of the shared transitway within the corridor.

Figure 2
Curb Shared and Median Shared Transitway

When a curbside transitway is in an exclusive lane, it does not integrate well with cloverleaf interchange ramps, such as those at the Washington Boulevard interchange. The merge and diverge operations required at cloverleaf ramp junctions are already challenging for many drivers; requiring all traffic to merge across an exclusive transitway aggravates the condition. Consequently, in the Phase 2 transit study, when an exclusive transitway would otherwise pass a cloverleaf interchange at curbside, it was transitioned to the median to reduce the conflict. This transition applies to the VISSIM models used in the current study as well.

Figure 3 presents a schematic diagram of a typical intersection in the Curb Shared alternative, depicting the treatment of transit stations and left turns.

Figure 3
Schematic Diagram of Typical Curb Shared Intersection



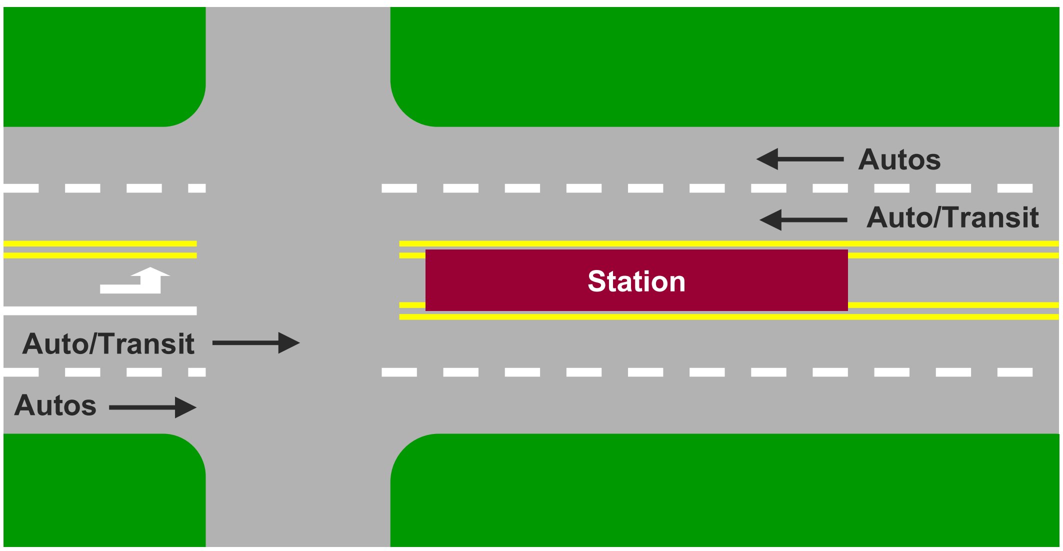
In the Curb Shared alternative, transit stations would be positioned at the curbside, integrated with adjacent sidewalks. Transit vehicles would stop in the curb lane to load and unload passengers at stations, which would delay automobile traffic in the curb lane.

The presence of the curb shared transitway would not significantly impact left-turning traffic. Left-turn lanes would be provided at major intersections, such as Glebe Road, George Mason Drive, and Walter Reed Drive, but at other intersections, left-turn storage bays would not be provided unless they already exist.

Median Shared

In the Median Shared alternative, like the Curb Shared, transit vehicles would operate mixed with automobile traffic on Columbia Pike between Jefferson and Washington. (Figure 2 applies to the Median Shared as well.) Unlike the Curb Shared, however, transit vehicles would occupy the left lane of traffic. This would allow transit vehicles to avoid conflicts with right-turning automobile traffic. Figure 4 shows a schematic diagram of a typical intersection in this configuration.

Figure 4
Schematic Diagram of Typical Median Shared Intersection



In the Median Shared alternative, transit stations would be located in the center of the street, so passengers would need to cross one direction of Columbia Pike traffic to reach a station. Therefore, all transit stations would be located at traffic signals to allow passenger access. As shown in Figure 4, a single station platform could serve transit vehicles traveling in both directions, reducing the amount of roadway width needed for stations.

Left turns would be particularly challenging in the Median Shared alternative. A stopped vehicle waiting to turn left at a location without a left-turn bay could delay transit vehicles. As such, left-turn storage bays were modeled at most intersections.

However, providing for left-turns near transit stations would be much more challenging. In Figure 4, note that the installation of a transit station would cause the removal of the left-turn storage bay for westbound traffic. If a left-turn bay were provided for westbound traffic, transit vehicles would have to stop in the left-turn bay to load and unload passengers and then merge back into through traffic, an undesirable operation. Lack of a left-turn bay would also be undesirable, because the left lane would then carry through traffic, left-turning traffic, and stopped transit vehicles. These different types of vehicles would be stopped at different times, causing delays to each other.

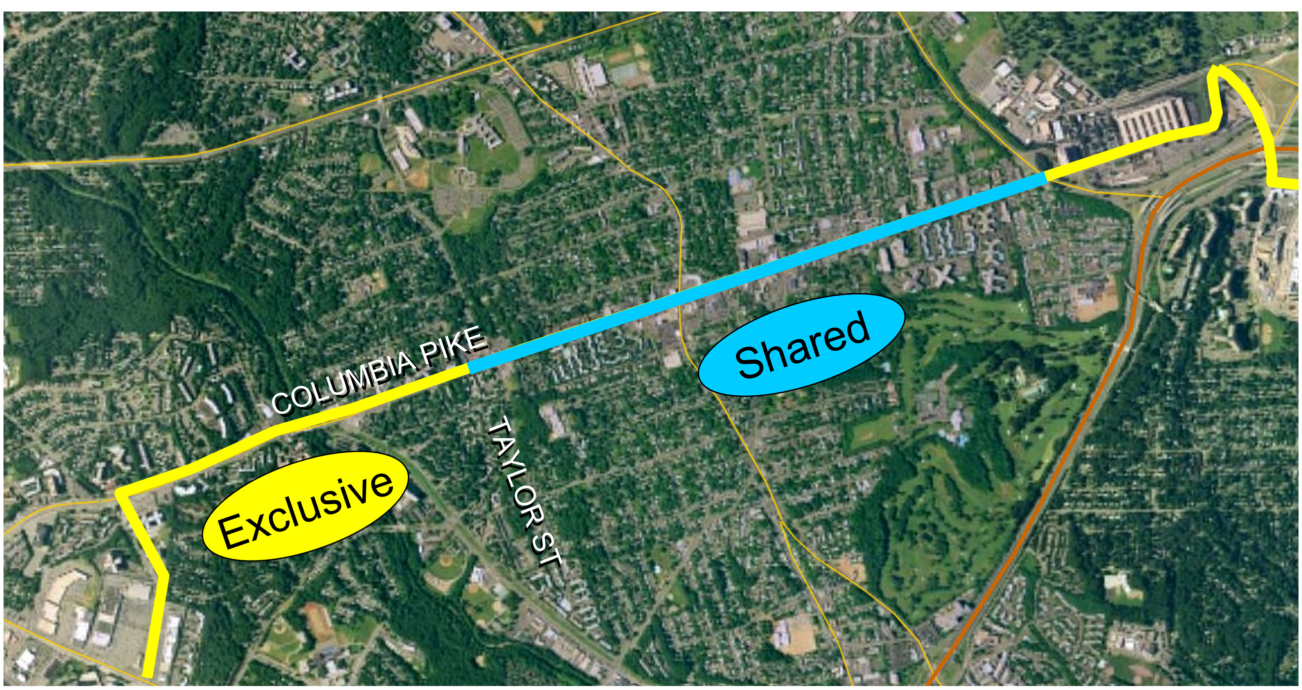
This conflict would only occur in one direction of travel at each affected intersection. At most transit stations in the Median Shared alternative, a left-turn bay was not modeled in the affected direction of travel. However, at two locations, where left-turning volume is high, a left-turn bay was modeled in the Median Shared in the affected direction, despite the need for transit vehicles to make the undesirable merge from the left-turn lane to the left-most through lane. These locations were George Mason Drive (for westbound traffic) and Courthouse Road (for eastbound traffic).

The median transitway would also require that transit vehicles have passenger doors on the left sides, an uncommon configuration for traditional buses. Transit vehicles with left-side doors could certainly be acquired to serve median stations, but traditional buses would not be able to use the median stations. Any traditional bus service on Columbia Pike would require additional stations at the curbside.

Curb Varies

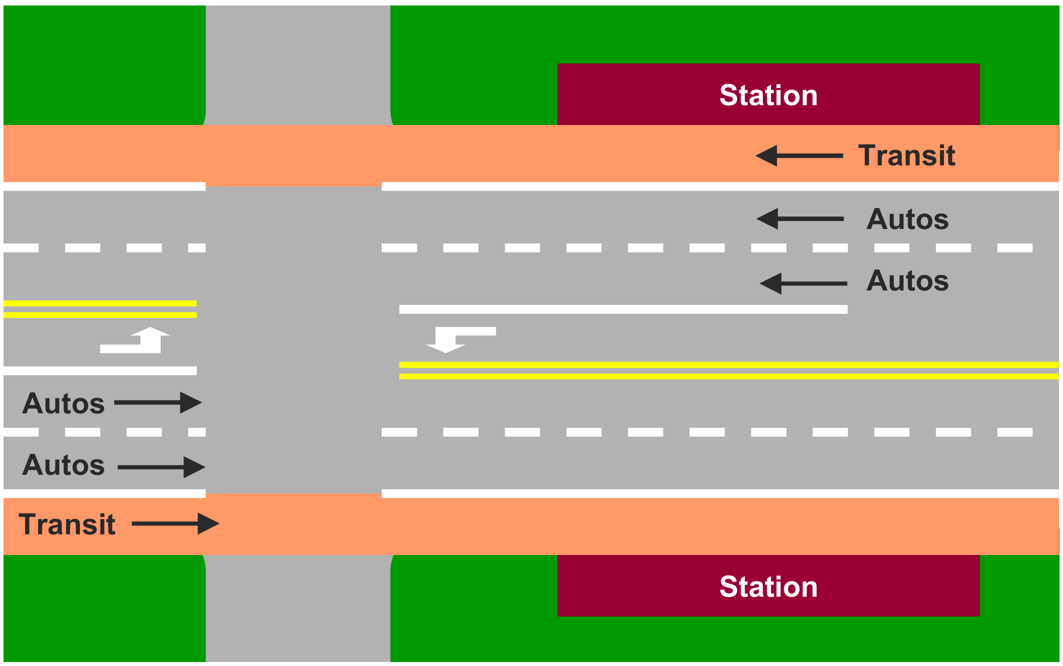
The Curb Varies alternative is identical to the Curb Shared east of Taylor Street, but west of Taylor Street, the transitway transitions to an exclusive lane, as shown in Figure 5.

Figure 5
Curb Varies and Median Varies Transitway



East of Taylor Street, the schematic diagram in Figure 3 applies to the Curb Varies alternative, but west of Taylor Street, the diagram in Figure 6 applies.

Figure 6
Schematic Diagram of Typical Curb Varies Intersection West of Taylor Street

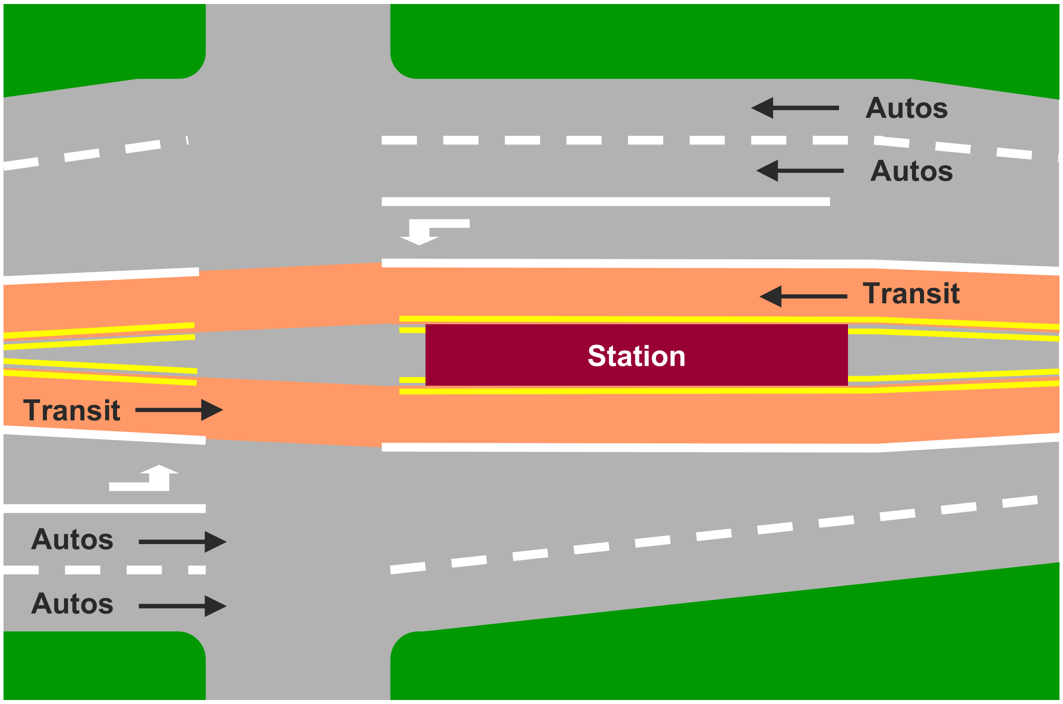


Despite the wider street cross-section, the exclusive curbside transitway west of Taylor Street would have little impact on either transit stations or left-turn treatment. Transit stations could continue to be integrated with adjacent sidewalks, and left-turning bays were modeled only at major intersections and where they currently exist.

Median Varies

The Median Varies alternative would also use a shared transitway east of Taylor Street and an exclusive transitway west of Taylor, as shown in Figure 5. Moving the transitway to the median would result in a schematic diagram in the eastern portion of the corridor matching Figure 4. A diagram of the western portion of the corridor is presented in Figure 7.

Figure 7
Schematic Diagram of Typical Median Varies Intersection West of Taylor Street



Like the Median Shared alternative, transit stations would be located at traffic signals to ensure convenient passenger access.

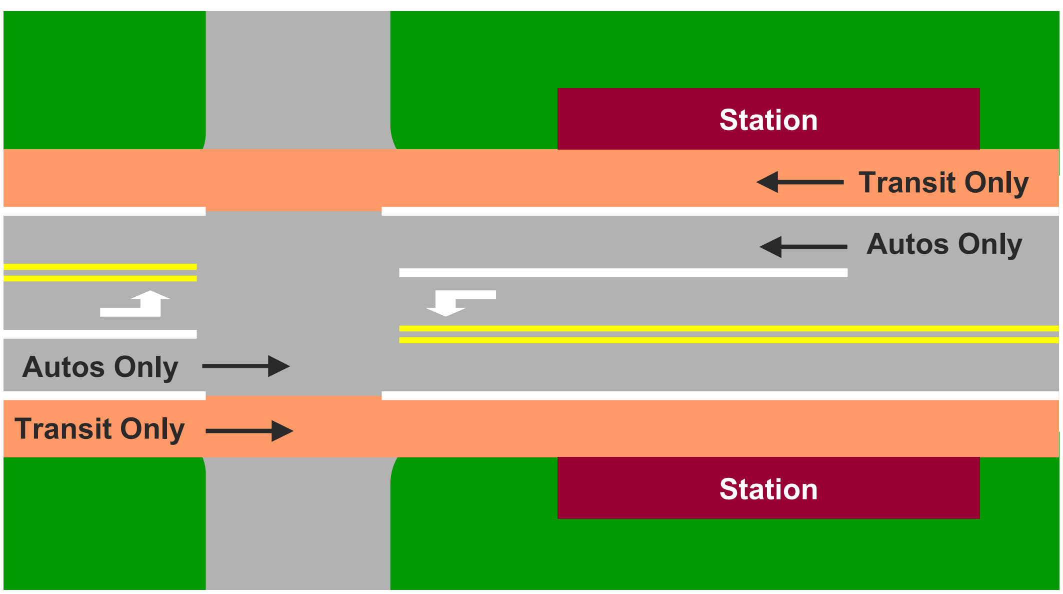
In the shared section east of Taylor Street, the left-turn treatment would be identical to the Median Shared alternative. West of Taylor Street, the transitway would be in exclusive right-of-way in the median, and this configuration demands careful left-turn consideration. When a transitway is in an exclusive lane in the median, traffic signals must be modified to permit left turns only when a green arrow is displayed. This restriction is necessary to prevent conflicts between transit vehicles and left-turning traffic. Left turns would be prohibited at locations without a left-turn arrow and a storage bay, including driveways and minor side streets. Drivers who were unable to make left turns at desired locations would reroute elsewhere, such as by making a U-turn at the next traffic signal.

Curb Exclusive

The Curb Exclusive alternative would retain approximately the same roadway width as currently exists, but it would convert the curb lanes for the exclusive use of transit vehicles, limiting automobile traffic to only the left lane. A location view is shown in Figure 8 and an intersection diagram is shown in Figure 9.

Figure 8
Curb Exclusive and Median Exclusive Transitway

Figure 9
Schematic Diagram of Typical Curb Exclusive Intersection

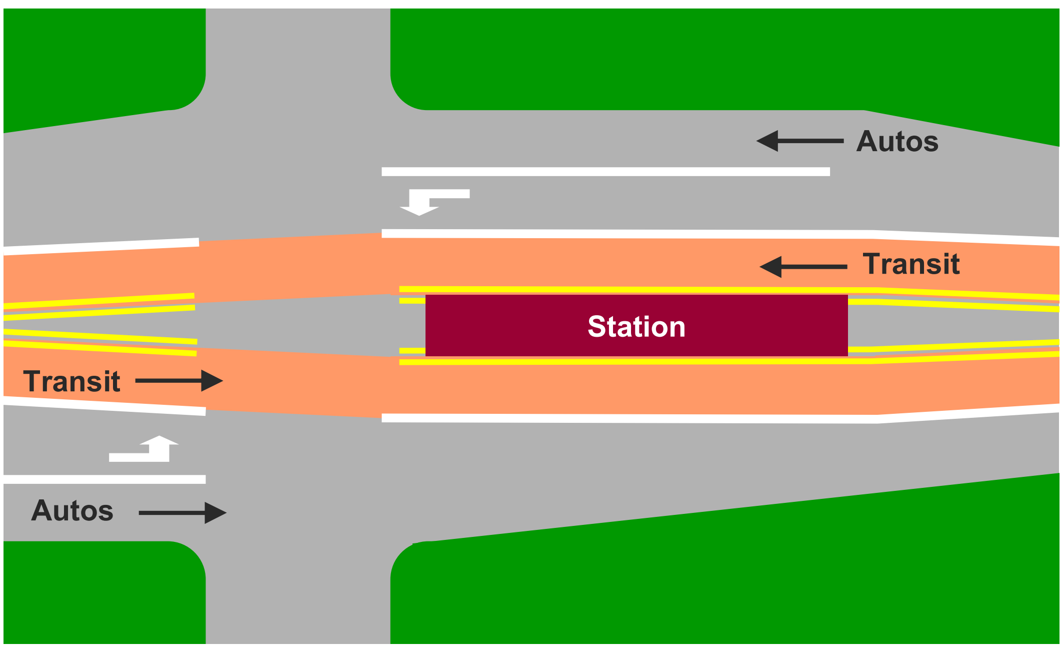


In the Curb Exclusive alternative, transit station access would be similar to other curbside transitway alternatives. However, all through traffic would be confined to a single lane, so left-turn bays would become critical. Without a left-turn bay, a vehicle stopped to make a left turn could significantly delay through traffic. Left-turn lanes were thus modeled at all intersections where significant left-turning traffic was expected. Left turns could be permitted at driveways and minor intersections without storage bays unless specifically prohibited, but even occasional interruptions in the flow of through traffic would be detrimental to traffic conditions.

Median Exclusive

Figure 8 above applies to the Median Exclusive alternative, and a typical intersection diagram is shown in Figure 10.

Figure 10
Schematic Diagram of Typical Median Exclusive Intersection



The Median Exclusive alternative would have transit station characteristics like other median transitway alternatives. As in the Curb Exclusive, left-turn bays would be needed to allow through traffic to bypass stopped vehicles waiting to turn left. But in the Median Exclusive, the need for left-turn bays would be especially acute, because the exclusive median transitway demands left-turn arrows and storage bays to avoid conflicts between transit vehicles and left-turning automobile traffic. The Median Exclusive alternative would share this characteristic with the western portion of the Median Varies.

Measures of Effectiveness

While a model is under analysis with VISSIM, information about each vehicle, such as its location and speed, are documented. Statistics are also maintained for each of the model's intersections. At the conclusion of a model run, a summary of these statistics is provided for review and analysis.

Each of the study's alternatives can be compared to the "No-Build" alternative; that is, an alternative that assumes that today's transit service continues in the 2020 design year. The No-Build also assumes the same moderate increase in traffic volumes as the other alternatives. The No-Build model is a more accurate basis for comparison than existing conditions, because by 2020, traffic conditions will be more congested than today.

In this study, the following three primary statistics—measures of effectiveness—were chosen as means of quantitatively comparing the alternatives:

Intersection Throughput

Intersection throughput is a measure of the number of vehicles passing through an intersection during a given time period. Throughput is a way to determine whether the intersection is able to serve all the vehicular demand. For example, if the demand for a certain traffic movement is 1,000 vehicles per hour and intersection throughput is also 1,000 vehicles per hour, then the demand is fully satisfied. However, if intersection throughput only measured 600 vehicles per hour, then the intersection would not be accommodating the full demand for service. In this case, 400 vehicles per hour would be unable to pass through the intersection.

In a microscopic simulation program such as VISSIM, intersection throughput seldom matches demand exactly. Random fluctuations in vehicle arrivals and departures usually cause throughput to be slightly higher, or, more commonly, slightly lower than demand.

If demand exceeds the capacity of an intersection, some vehicles are not able to pass through because of excessive congestion. The VISSIM models do not predict vehicles' reactions to the congestion. Some vehicles may choose to take alternate routes, others may switch travel modes, and still others may be willing to wait longer to pass through. Although VISSIM does not model the *reaction* to congestion, its modeling of the location and magnitude of the congestion is accurate.

Intersection Performance

If an intersection's throughput indicates that demand is being satisfied, then the performance of the intersection can be evaluated based on the amount of delay vehicles experience as they pass through the intersection. A vehicle's delay is equal to the amount of time the vehicle loses while it is traveling slower than its desired speed in response to either the signal's indication or a queue of other vehicles observing the signal.

The average intersection delay is determined by averaging the individual delays from all vehicles approaching the intersection from all directions during the entire simulation run. Some vehicles may be able to pass through an intersection without experiencing any delay, as when the light is green and there are no stopped vehicles. These "zero-delay" vehicles are included in the computation of average delay. For example, if nine vehicles pass through an intersection on the major street with zero delay, and one vehicle one the minor street is delayed at a red light by 100 seconds, the average delay would be 10 seconds per vehicle.

In this study, intersection performance is grouped into three categories:

- Intersections classified as "good" experience very low average delays of less than 20 seconds per vehicle. At this level, many vehicles approaching an intersection are not required to stop, and service to minor-street traffic is efficient. This category corresponds to levels of service A and B as defined by the *Highway Capacity Manual 2000* methodology for evaluating signalized intersections.
- Intersections classified as "fair" experience moderate average delays of between 20 and 60 seconds per vehicle. Intersections at this level are notably more congested than those in the good range, but not so congested that demand cannot be satisfied. The lower end of the fair range is often taken as the lowest desirable intersection performance in urban areas. This category largely corresponds to levels of service C and D in the *Highway Capacity Manual.*
- Intersections classified as "poor" experience very high average delays of greater than 60 seconds per vehicle. Poor intersections often occur where the volume of approaching traffic is higher than the signal's ability to process the volume, causing individual vehicles to wait more than one change of the signal. Many engineers attempt to avoid allowing intersections to operate in this category, which largely corresponds to *Highway Capacity Manual* levels of service E and F.

Travel Time

More than throughput or delay, travel time offers a measure of effectiveness that can be easily understood by most roadway users. Travel time measures the average amount of time required for a vehicle to traverse a specific roadway segment. Travel time measures are kept separately for both automobile and transit traffic. In this study, travel time was measured for eastbound traffic along Columbia Pike between Jefferson Street and the Washington Boulevard overpass. This segment of Columbia pike measures about 2.6 miles in length.

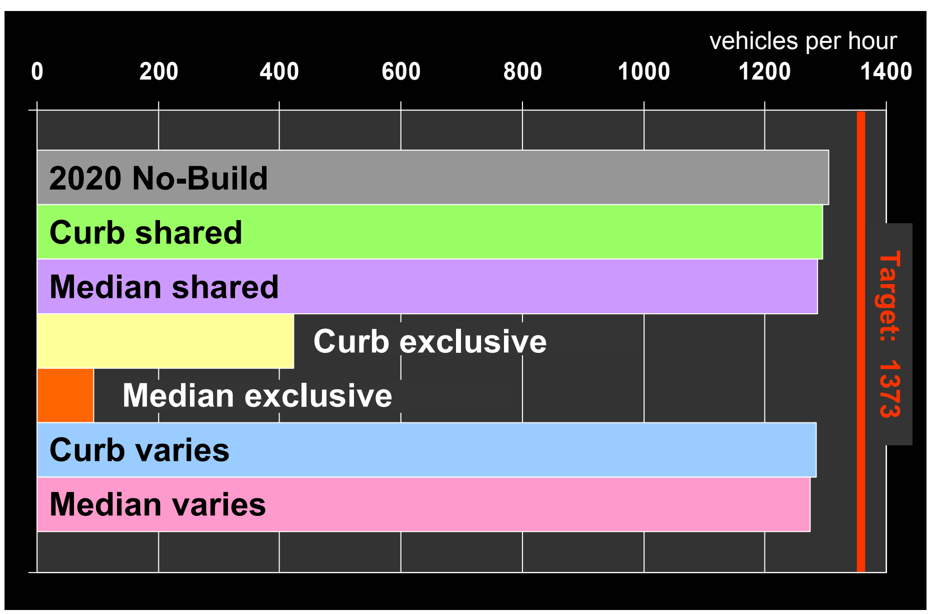
When both travel distance and travel time are known, average travel speed can be computed as their ratio. *Average travel speed* must be differentiated from *desired speed* discussed earlier. A vehicle's desired speed is the speed the vehicle would choose to travel if the signals were green and no other traffic were present. The vehicle's average travel speed is the actual average speed the vehicle is able to observe, considering the presence of traffic control devices and other vehicles. Average travel speed will never exceed desired speed. For instance, if a vehicle has a desired speed of 40 mph, that vehicle may occasionally travel as fast as 40 mph on a street where there is little traffic and the signals are spaced far apart. However, this vehicle will never travel faster than 40 mph, and it will often travel less than 40 mph if impeded by other traffic. Occasionally this vehicle will stop completely to observe traffic signals. Over a long street segment, the vehicle may attain an average travel speed of 20 mph.

Results of Simulation

Intersection Throughput

Figure 11 presents intersection throughput results for eastbound through traffic on Columbia Pike at George Mason Drive. At George Mason Drive, the "target" demand for eastbound traffic, indicated by the vertical red line on the right side of the figure, is 1,373 vehicles per hour. At this intersection, there are thus 1,373 vehicles predicted to demand service during the morning peak hour.

Figure 11
Eastbound Throughput on Columbia Pike at George Mason Drive

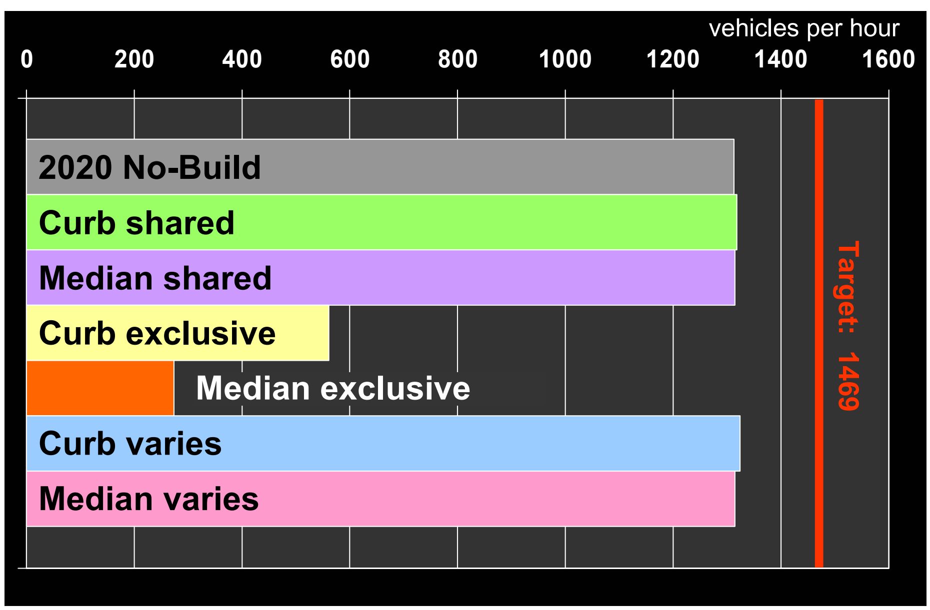


In the No-Build alternative, Figure 11 shows that about 1,300 vehicles per hour would be processed, about 95 percent of the demand volume. The four Shared and Varies alternatives would process about the same level of traffic as the No-Build, ranging from 1275 to 1295 vehicles per hour. These differences are within only a few percentage points of each other and are not statistically significant.

In contrast, the two Exclusive alternatives would show much lower throughputs of about 400 vehicles per hour for the Curb Exclusive and 100 vehicles per hour for the Median Exclusive. The Curb Exclusive could thus process only about 30 percent of demand volume, while the Median Exclusive could process less than 10 percent of demand volume. Figure 11 clearly shows that these two alternatives, in which all automobile traffic is confined to a single lane, would be unable to satisfy the traffic demand.

Figure 12 presents an additional chart of eastbound throughput, this time at Glebe Road. The pattern at Glebe is nearly identical to George Mason, with the Exclusive alternatives lagging far behind the others. At Glebe, the demand volume is slightly higher, at 1,469 vehicles per hour. The No-Build, along with the Shared and Varies alternatives, could all process between 89 and 90 percent of demand volumes, while the Curb Exclusive could satisfy less than 40 percent of demand and the Median Exclusive could satisfy less than 20 percent of demand.

Figure 12
Eastbound Throughput on Columbia Pike at Glebe Road



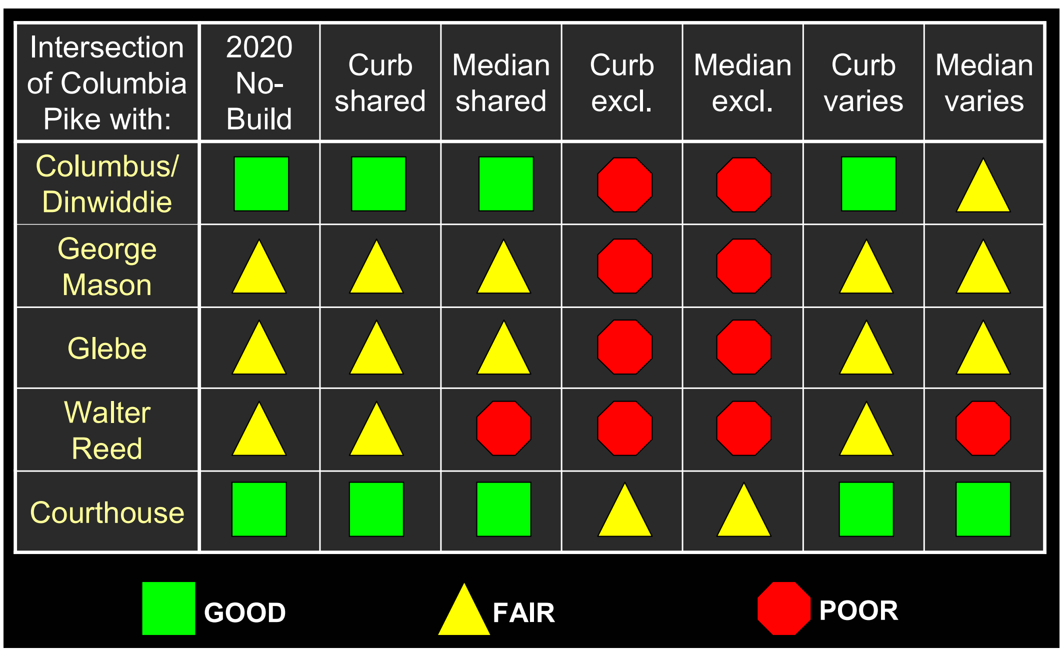
At both George Mason and Glebe, none of the alternatives would be able to satisfy 100 percent of the demand for automobile traffic. This suggests that traffic volumes were predicted to increase at a rate that is slightly larger than the existing roadway network could support.

Detailed results of intersection throughput at these two intersections, as well as at other signalized intersections in the corridor, are presented in Appendix A.

Intersection Performance

Figure 13 presents a matrix showing the performance of key intersections in each of the six Build alternatives and the No-Build. Both the Exclusive alternatives would show poor operational conditions at most intersections, as would be expected based on the low throughput results.

Figure 13
Columbia Pike Intersection Performance



In the No-Build alternative, three intersections—George Mason Drive, Glebe Road, and Walter Reed Drive—would operate in the fair range, while the rest of the network would operate in the good range. The Curb Shared and Curb Varies alternatives would be very similar to the No-Build, with no changes in performance range at any of the five reported intersections. This similarity acknowledges that these two alternatives have transit operational characteristics much like the No-Build, with transit vehicles operating at the curbside, largely in mixed traffic.

In the Median Varies alternative, conditions at the Columbus/Dinwiddie intersection would drop from good to fair. In the Median Varies, at intersections west of Taylor Street, left turns can only be accommodated on green arrows, causing substantial increases in delay to both left-turning and through traffic. This increase in delay would be enough to drop the performance level of this intersection.

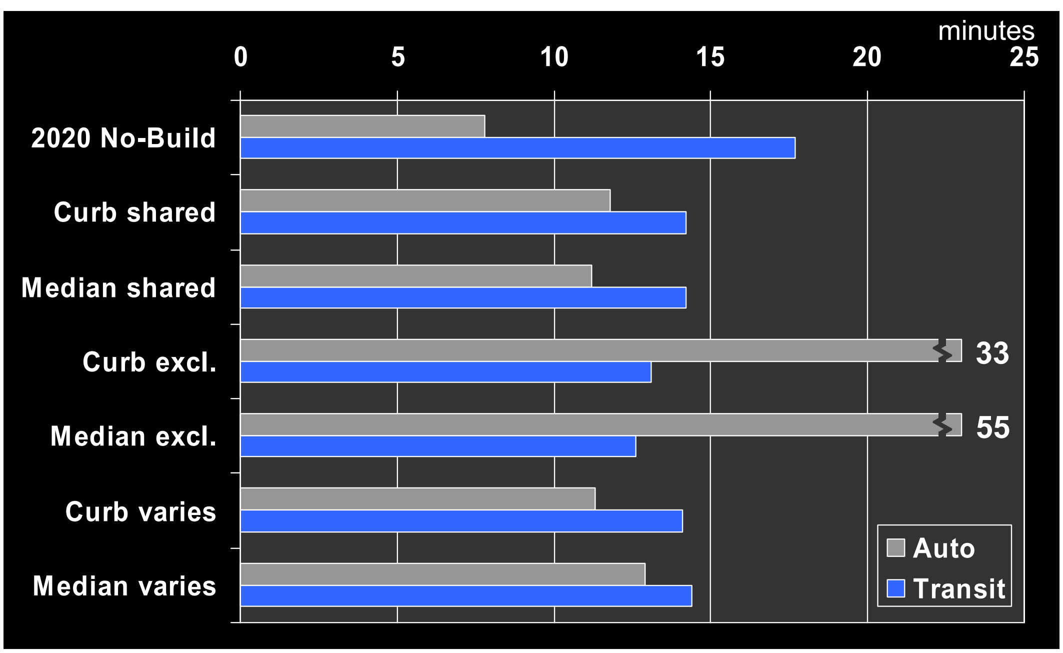
In both Median Shared and Median Varies alternatives, conditions at Walter Reed Drive would drop into the poor range. Again, left-turn difficulties are likely to blame.

The five intersections reported in Figure 13 are those with the heaviest congestion in the network. Most other intersections would operate in the good range in all alternatives, but results from all signalized intersection are reported in Appendix A.

Travel Time

Figure 14 presents travel time results for each alternative, for both automobiles and transit vehicles. In the No-Build alternative, automobiles could traverse the segment between Jefferson Street and Washington Boulevard in about 8 minutes, while Metrobuses would require about 18 minutes. These travel times translate to average travel speeds of 20 mph for automobile traffic and 9 mph for buses.

Figure 14
Eastbound Travel Times on Columbia Pike, Jefferson Street – Washington Boulevard



Each of the six Build alternatives would result in longer automobile travel times than the No-Build, but the slower auto travel would be largely due to the lower desired speeds modeled in the Build alternatives. Using similarly low desired speeds in the No-Build alternative would likely cause its auto travel times to lengthen to levels comparable with the Shared and Varies alternatives.

Despite the reduction in desired speed, transit travel time improved in each of the six Build alternatives when compared to the No-Build. Three primary factors led to the improvement in transit operations:

- The consolidation of transit stations permit transit vehicles to stop less frequently to load and unload passengers. Between Jefferson Street and Washington Boulevard, there are 19 existing bus stops; the Build alternatives model just nine transit stations in this same section.
- As discussed earlier, traffic signal priority was given to transit vehicles.
- In the Build alternatives, the transit system was modeled assuming that passengers would pay fares at stations, rather than on board vehicles. This off-vehicle fare-payment system helps speed boarding, because passengers can board a transit vehicle using multiple doors, instead of just the front door.

(Transit travel time could be improved further by increasing the desired speeds, which affect transit vehicles and automobiles alike.)

Automobile travel times in the Exclusive alternatives would be extremely long—over 30 minutes for the Curb Exclusive and nearly a full hour for the Median Exclusive. As with previous results, the Exclusive alternatives have demonstrated that they would be unable to satisfactorily serve traffic volumes.

However, the Exclusive alternatives would have the fastest transit travel times, at 13 minutes. This travel time correlates to an average transit speed of 12 mph, and since transit vehicles would have their own lane for the entire length of the segment, this travel time could be considered a lower boundary of travel time for the studied conditions.

Despite the inclusion of an exclusive transit lane for a portion of the Varies alternatives, these alternatives would not offer a substantial travel time improvement over the Shared alternatives. Travel times in the Curb Varies would be less than a minute shorter than in the Curb Shared. In the Median Varies, travel times would be actually slightly longer than in the Median Shared, even with a wider cross-section. This increase is due to the more difficult left turn provisions when the transitway is in exclusive right-of-way in the median.

Transit travel times would not fluctuate much among all four Varied and Shared alternatives, remaining near 14 minutes for each, or an average travel speed of about 11 mph.

In addition, little travel time difference would exist among curbside and median transitway alignments. Travel times would be slightly shorter in the Median Shared alternative compared with the Curb Shared, but travel times would be slightly longer in the Median Varies than the Curb Varies.

Complete travel time results for both eastbound and westbound traffic are presented in Appendix A.

Discussion

Traffic simulation results led to several observations:

- Constructing a high-capacity transit system would improve the average travel time for transit vehicles, regardless of the configuration chosen. Much of the improvement would likely be due to a reduction in the number of transit stations, implementation of traffic signal priority for transit vehicles, and off-vehicle fare-payment systems that would reduce the time needed for each stop.
- To meet the demand for vehicular travel, automobile traffic would need two lanes in each direction, even if one lane is shared with transit vehicles.
- Adding an exclusive transit lane west of Taylor Street would not offer a significant improvement in travel time for either automobiles or transit vehicles. However, this study can only draw conclusions about the exclusive transitway west of Taylor Street. East of Taylor, streets intersecting Columbia Pike have higher volumes than streets to the west, so an exclusive transitway may have a larger impact on travel times.
- The low desired speeds used in the study, 20 mph in activity centers and 25 mph between centers, would lengthen average travel times of both automobiles and transit vehicles. Additional simulation would be needed to show the effects of higher desired speeds, but it is possible that higher speeds would show larger impacts of the exclusive transitway.
- The simulation results do not show significant travel time or throughput differences between curbside and median transitways, although the left-turn difficulties of the median transitway hamper performance of a few intersections.

Appendix A: Detailed Results of Traffic Simulation

		Eastbound Throughput: Shortage/Surplus (Percent of target)						
Intersection of Columbia Pike with	Target	2020 No-Build	Curb varies	Median varies	Curb shared	Median shared	Curb exclusive	Median exclusive
Jefferson	1498	-57 (96)	-134 (91)	-68 (95)	-105 (92)	-72 (95)	**-1106 (26)**	**-1419 (5)**
Greenbrier	1623	-51 (96)	-115 (92)	-80 (95)	-89 (94)	-74 (95)	**-1165 (28)**	**-1540 (5)**
Frederick	1686	-105 (93)	-163 (90)	-140 (91)	-138 (91)	-142 (91)	**-1220 (27)**	**-1607 (4)**
Dinwiddie	1757	-69 (96)	-124 (92)	-89 (94)	-102 (94)	-100 (94)	**-1425 (18)**	**-1672 (4)**
Four Mile Run	1864	-86 (95)	-125 (93)	-116 (93)	-107 (94)	-109 (94)	**-1376 (26)**	**-1767 (5)**
Buchanan	1816	-140 (92)	-179 (90)	-163 (91)	-164 (90)	-157 (91)	**-1317 (27)**	**-1732 (4)**
Wakefield	1750	-61 (96)	-88 (94)	-84 (95)	-82 (95)	-73 (95)	**-1219 (30)**	**-1660 (5)**
Taylor/Thomas	1792	-109 (93)	-132 (92)	-127 (92)	-130 (92)	-124 (93)	**-1237 (30)**	**-1668 (6)**
George Mason	1373	-68 (95)	-88 (93)	-99 (92)	-78 (94)	-86 (93)	**-950 (30)**	**-1280 (6)**
Quincy	1598	**-228 (85)**	**-248 (84)**	**-260 (83)**	**-244 (84)**	**-243 (84)**	**-1082 (32)**	**-1424 (10)**
Monroe	1520	-147 (90)	-124 (91)	-151 (90)	-130 (91)	-133 (91)	**-972 (36)**	**-1308 (13)**
Glebe	1469	**-157 (89)**	-145 (90)	**-154 (89)**	**-151 (89)**	**-154 (89)**	**-908 (38)**	**-1195 (18)**
Highland	1539	**-202 (86)**	**-207 (86)**	**-236 (84)**	**-225 (85)**	**-219 (85)**	**-948 (38)**	**-1192 (22)**
Walter Reed	1532	**-274 (82)**	**-221 (85)**	**-201 (86)**	**-243 (84)**	**-183 (88)**	**-897 (41)**	**-1076 (29)**
Barton	1854	-167 (90)	-150 (91)	-126 (93)	-184 (90)	-88 (95)	**-1047 (43)**	**-1047 (43)**
Wayne	1935	-101 (94)	-65 (96)	-53 (97)	-95 (95)	-26 (98)	**-968 (49)**	**-953 (50)**
Court House	1881	-95 (94)	-47 (97)	-28 (98)	-79 (95)	-2 (99)	**-889 (52)**	**-943 (49)**
Quinn	2542	**-296 (88)**	**-356 (86)**	-225 (91)	**-395 (84)**	-213 (91)	**-1351 (46)**	**-1281 (49)**

	Intersection Delays: LOS (Average delay per vehicle)						
Intersection of Columbia Pike with	2020 No-Build	Curb varies	Median varies	Curb shared	Median shared	Curb exclusive	Median exclusive
Jefferson	A (8)	B (11)	B (14)	B (15)	B (15)	**F (105)**	**D (43)**
Greenbrier	A (6)	A (8)	B (11)	A (7)	A (7)	**E (69)**	**D (38)**
Frederick	A (7)	B (12)	B (18)	B (14)	B (12)	**F (89)**	**C (33)**
Dinwiddie	B (19)	**C (24)**	**D (37)**	**C (22)**	**C (24)**	**E (77)**	**F (94)**
Four Mile Run	B (15)	B (18)	B (19)	B (16)	B (12)	**F (93)**	**E (78)**
Buchanan	B (10)	A (10)	B (15)	B (12)	A (7)	**D (43)**	**F (95)**
Wakefield	A (8)	A (6)	B (15)	A (6)	A (7)	**E (59)**	**F (113)**
Taylor/Thomas	B (17)	A (10)	**C (33)**	B (15)	A (8)	**F (92)**	**F (174)**
George Mason	**C (29)**	**D (50)**	**D (52)**	**D (55)**	**D (52)**	**F (83)**	**F (200)**
Quincy	A (9)	**C (21)**	A (1)	**C (25)**	A (1)	**D (46)**	**F (83)**
Monroe	**C (27)**	B (16)	B (20)	B (15)	B (17)	**F (81)**	**F (124)**
Glebe	**D (39)**	**D (45)**	**D (39)**	**D (45)**	**D (42)**	**E (71)**	**F (90)**
Highland	B (12)	A (9)	A (7)	A (9)	A (7)	**E (70)**	**F (98)**
Walter Reed	**C (33)**	**E (55)**	**E (70)**	**E (57)**	**F (85)**	**F (205)**	**F (168)**
Barton	A (7)	B (16)	A (10)	B (16)	A (9)	**D (47)**	**C (28)**
Wayne	A (8)	A (7)	A (6)	A (7)	A (6)	**C (21)**	B (19)
Court House	B (11)	B (19)	B (14)	B (18)	B (15)	**C (30)**	**C (28)**
Quinn	B (12)	**C (25)**	B (15)	**C (22)**	B (17)	**C (33)**	B (19)

	Travel Times in Minutes (Average Speed in mph)													
	2020 No-Build		Curb varies		Median varies		Curb shared		Median shared		Curb exclusive		Median exclusive	
Eastbound	Auto	Transit	Auto	Transit	Auto	Transit	Auto	Transit	Auto	Transit	Auto	Transit	Auto	Transit
Jefferson to Taylor/Thomas	2 (25)	5.2 (9)	3.2 (15)	4 (12)	4.6 (11)	4.1 (12)	3.5 (14)	4.4 (11)	3.4 (14)	4.4 (11)	12.2 (4)	4.2 (12)	16.4 (3)	4.1 (12)
Taylor/Thomas to Glebe	2.4 (19)	5.2 (9)	3.3 (14)	4.1 (11)	4.3 (11)	4.4 (10)	3.7 (12)	4 (11)	3.6 (13)	3.9 (12)	11.5 (4)	3.4 (13)	26.7 (2)	3.2 (14)
Glebe to Wayne/Barton	1.9 (16)	3.9 (8)	2.2 (14)	2.8 (11)	2.1 (14)	3 (10)	2.2 (14)	2.8 (11)	2.1 (14)	2.9 (10)	6.2 (5)	2.7 (11)	9 (3)	2.8 (11)
Wayne/Barton to Washington	1.6 (21)	3.3 (10)	2.6 (13)	3 (11)	1.9 (17)	2.9 (11)	2.5 (13)	3 (11)	2 (16)	3 (11)	3.1 (11)	2.8 (12)	2.9 (11)	2.5 (13)
Jefferson to Washington	**7.8 (20)**	**17.7 (9)**	**11.3 (14)**	**14.1 (11)**	**12.9 (12)**	**14.4 (11)**	**11.8 (13)**	**14.2 (11)**	**11.2 (14)**	**14.2 (11)**	**33 (5)**	**13.1 (12)**	**55 (3)**	**12.6 (12)**
Westbound														
Washington to Wayne/Barton	1.2 (26)	3.6 (9)	1.7 (20)	2.8 (12)	1.4 (24)	2.3 (14)	1.7 (20)	2.8 (12)	1.4 (24)	2.3 (14)	1.8 (18)	2.8 (12)	1.8 (18)	2.3 (14)
Wayne/Barton to Glebe	1.7 (18)	4.3 (7)	2.4 (13)	2.8 (11)	2.1 (14)	2.8 (11)	2.4 (13)	2.9 (11)	2.1 (15)	2.8 (11)	2.8 (11)	2.7 (11)	3.5 (9)	2.6 (11)
Glebe to Taylor/Thomas	2.3 (20)	5.2 (9)	2.6 (17)	3.4 (14)	2.7 (17)	3.7 (13)	2.7 (17)	3.5 (13)	2.7 (17)	3.7 (13)	3.2 (14)	3.5 (13)	3.4 (14)	3.6 (13)
Taylor/Thomas to Jefferson	1.9 (26)	6.1 (8)	3 (17)	4.4 (12)	3.1 (16)	4.5 (11)	3 (17)	4.8 (11)	3 (17)	4.1 (12)	3.3 (16)	4.3 (12)	3.3 (15)	4.6 (11)
Washington to Jefferson	**7.2 (22)**	**19.2 (8)**	**9.7 (16)**	**13.3 (12)**	**9.3 (17)**	**13.3 (12)**	**9.8 (16)**	**13.9 (11)**	**9.1 (18)**	**12.9 (12)**	**11 (14)**	**13.3 (12)**	**12 (13)**	**13.2 (12)**

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