King County Metro

Roundabout Guidance

A tool for teams planning and designing roundabouts on King County bus routes

July 2024

King County METRO
Moving forward together

Table of Contents

Page

Figures and Tables

Acknowledgements

This guidance was developed by the following staff at King County Metro, building on the guidelines developed in 2014 by Community Transit, national guidance found in *NCHRP Research Report 1043: Guide for Roundabouts (2023)*, and King County Metro's *Transit Route Facilities Guidelines (2020)*. It incorporates references to *Public Right-of-Way Accessibility Guidelines (PROWAG) (2023)* for sidewalks and shared use pathways.[1]

Lisa Ballard
Capital Planning – Traffic Engineer
liballard@kingcounty.gov

Jacob Brett
Mobility, Service Development – Transportation Planner
jbrett@kingcounty.gov

Kale Chang Yuen, PE
Capital Project Delivery – Civil Engineer
kchangyuen@kingcounty.gov

Owen Kehoe, PE
Capital Planning – Traffic Engineer
owen.kehoe@kingcounty.gov

[1] As of the writing of this document, PROWAG is not yet enforceable, as it requires adoption by the U.S. Department of Transportation (USDOT) and U.S. Department of Justice (USDOJ). That said, PROWAG represents current best practices as the minimum requirements for accessibility in the public right-of-way.

1 Introduction and Purpose

This document aims to educate, inform, and foster coordination between King County Metro (Metro) and the various roadway authorities having jurisdiction (AHJ) when planning and designing a roundabout that impacts Metro bus operations.

Roundabouts are a proven safety measure that substantially reduces fatal and injury crashes. As roundabouts become more prevalent in the Puget Sound Region, there is a growing need to integrate these transit-specific considerations into the planning and design process. Metro's design preferences aim to:

- Ensure passenger safety by preventing onboard passengers from being jostled, slipping, falling, or losing possession of belongings;
- Enable bus operators to navigate through a roundabout safely and consistently without damaging the coach;
- Provide safe and convenient access for passengers at nearby stops;
- Promote transit speed and reliability.

The details included in this document serve as **Metro's guidance, supplementing local and state guidelines, standards, and requirements** when a jurisdiction considers a roundabout as an intersection control.

Metro operates a variety of transit coaches with different lengths and handling characteristics on roadways owned by other agencies, including the state (Washington State Department of Transportation, WSDOT), the county (King County Roads), and 39 towns and cities within the county. As the largest transit agency in Washington, Metro's 2,400 operators serve 256,000 passengers per weekday in a fleet of 1,500 buses[2]. Buses primarily operate on arterials in and between urbanized areas, with many routes running every 15 minutes or less throughout the day. Metro's RapidRide bus rapid transit service operates at the highest level of frequency and includes transit speed and reliability treatments designed to avoid traffic congestion.

This document is based on Metro's design and operating experiences and multiple references. Most existing research provides context on designing for large vehicles but offers limited details for bus operations. Metro would welcome partnerships with other jurisdictions to address the research gaps on bus operations in roundabouts.

Consider the following when designing roundabouts for buses:

- Design turning movements assuming buses will not traverse across the inner circle or mount the truck apron. Exercise caution when designing curbs and truck aprons to be mountable by bus wheels without jostling passengers.

[2] 2023 Quarter 4 data: https://kingcounty.gov/en/dept/metro/about/data-and-reports

- Coordinate with Metro on multilane roundabouts to determine the desired design approach for bus operations - whether the design will keep buses in-lane or straddle lanes.
- Use the appropriate bus design vehicle settings for vehicle maneuver software (i.e. AutoTURN) analysis.
- Review the design of raised crosswalks for vertical bus clearance.
- Consider pedestrian comfort and safety as well as bus operations as it relates to bus stop placement, grading, and pedestrian pathways.
- Consider signalization, signage, and priority access for transit speed, reliability, and safety.

Each roundabout design is context sensitive, based on the specifics of the geography and built environment. Metro acknowledges there are elements that may preclude prioritizing buses. As a result, the document articulates desired design features and acknowledges the need for flexibility when practical and necessary.

In summary, Metro is offering guidance and consultation to jurisdictions considering a roundabout on roadways with existing or future transit service. Consulting with Metro and this guidance can help planners, engineers, and stakeholders incorporate transit design considerations early so coordination is streamlined, and ultimately, local transit riders can expect a safe journey. In circumstances where Metro's guidance cannot be met, Metro requests an opportunity to collaborate with the jurisdiction to best meet transit needs in a way that maximizes safety for everyone using roundabouts.

2 Transit-Friendly Roundabouts Checklist

Metro is providing this roundabout use and transit design considerations checklist for interagency partners, developers, and consultants. Agencies and jurisdictions planning roundabouts should engage Metro as early as possible to coordinate when there is current or future transit service at a possible roundabout location.

- **Coordination with Metro: Planning and Concept Phase**
  - ☐ Contact plansreview@kingcounty.gov or reach out directly to your Metro project contact as early as possible to review and tailor this list collaboratively.
  - ☐ Identify bus routes and bus stops on the roadway where the roundabout is planned. Resources:
    - King County Transit Route map – click on the link to view current routes.
    - King County Bus Stop Map – zoom in to see individual stops.
    - Metro Connects Maps – click on the link to view future routes planned in the *Metro Connects Interim Network* and *Metro Connects 2050 Network*.
  - ☐ Identify site constraints that may impact transit operations.
  - ☐ Describe the planning and design approach as it relates to transit operations and transit access considerations.
  - ☐ Share design concepts with Metro early, including the assumed type of roundabout (mini, compact, single lane, or multi-lane).
  - ☐ Share traffic analysis including expected level of service and queue length.
  - ☐ Consult early with Metro if considering mini-roundabouts or compact roundabouts on transit routes. These designs are particularly challenging to transit operations and can significantly impact transit routing (Section 3.1).

- **Multilane Roundabouts: Planning and Concept Phase**
  - ☐ Include Metro in the performance-based planning and design process in designing for buses to operate in lane or by splitting lanes (See Section 4.2).[3]
  - ☐ Provide vehicle maneuver software (i.e., AutoTURN) results of in-lane operations and a comparison to splitting lanes during early design.
  - ☐ For multilane roundabout designs that assume buses stay in their lane, use best practices identified in NCHRP 1043 to keep buses from drifting into adjacent lanes.

---

[3] Splitting lanes is a non-standard movement for Metro operations. Metro prefers designs for buses to stay in lane but recognizes this will increase the size of the roundabout, increase operating speeds, and impact safety. In places with high pedestrian volumes, Metro may favor roundabouts designed for lane splitting due to lower operating speeds.

- **Bus Stops and Pedestrian Access: Planning and Concept Phase**
  - ☐ Coordinate between Metro and any Authorities Having Jurisdiction (AHJ) on bus stop location and design.
  - ☐ See Section 4.3 for factors and reasoning in considering near-side or far-side stops at a roundabout.
  - ☐ Avoid in-lane near-side stops at multilane roundabouts: Metro prefers in-lane near-side stops at single lane roundabouts but prefers far-side in-lane stops at multilane roundabouts (See Section 4.3).
  - ☐ Locate stops before the crosswalk when near-side, after the crosswalk when far-side.
  - ☐ Provide a conceptual exhibit(s) showing bus stop locations and types with supporting logic.
  - ☐ Site stops to minimize pedestrian out-of-direction travel, if possible.
  - ☐ Account for increased pedestrian volumes near future transit stations and mobility hubs.

- **Coordination with Metro: Design Phase**
  - ☐ Once available, send details to plansreview@kingcounty.gov. This is standard operating procedure with AHJ on all projects on King County bus travel ways.
  - ☐ Provide signage and striping plans with dimensions.
  - ☐ Provide paving plans and curbing details.
  - ☐ Provide truck apron details.
  - ☐ Provide typical sections showing proposed cross slope at entries and in circulating roadway.
  - ☐ Include details at raised crosswalks, if applicable.
  - ☐ Provide the estimated design submittals, 100% design/final design date, construction date, completion date, and timeline updates.

- **Bus Stops and Pedestrian Access: Design Phase**
  - ☐ Work with your point of contact at Metro and the Transit Route Facilities team to determine bus lengths and number of buses to be accommodated at new bus stop locations.
  - ☐ Ensure that ample space is provided for boarding at the bus door(s). Design the stop platform and approaching curves so both doors of the bus align with the curb (see Section 4.3).
  - ☐ Ensure that sightlines for pedestrian crossings are not obstructed.
  - ☐ If applicable, ensure bus has sufficient clearance at raised crosswalks.
  - ☐ Communicate potential construction impacts (like bus stop relocation) for existing bus stops.

- **Design Vehicles, Vehicle Maneuver Software, and Swept Path Diagrams**
  - ☐ Provide swept path diagrams that reference to Metro's design vehicle and vehicle maneuver software (i.e., AutoTURN) specifications (see Section 4.1).

- ☐ Use appropriate design vehicles for Metro Transit (Section 4.1). Additional details for Metro vehicle maneuver software settings are available in Chapter 3.3 of Metro's Transit Route Facilities Guidelines.
- ☐ Ensure that mirrors and bike racks are included in the transit design vehicle envelopes.
- ☐ Analyze turning movements with buses maintaining a 5-10 mph speed throughout the roundabout.
- ☐ Ensure buses can navigate the roundabout(s) without driving on truck aprons or curbs.
- ☐ Consider a sloped curb on truck aprons as shown in Section 4.7 instead of a rolled curb, as buses may occasionally track onto the truck apron despite design allowances.
- ☐ Provide vertical clearance details of buses at raised crosswalks, truck aprons, and entry/exit points.

- **Signage**
  - ☐ Optionally include signage such as "Trucks and Buses may use both lanes" for multi-lane roundabouts.

3 Planning, Project Development, and Concept Development

This section provides more details on coordinating with Metro throughout the planning and concept phases.

3.1 Roundabout Definition and Characteristics

NCHRP 1043 defines a roundabout as "a circular intersection form in which traffic travels counterclockwise around a central island and entering traffic must yield to circulating traffic." This document does not apply to traffic calming circles or rotaries. Traffic calming circles are common in King County, have smaller diameters than typical roundabouts, and usually are not suitable for Metro operations. Rotaries, which are distinguished by having large diameters often greater than 300 ft, are not common in Washington.

Table 1 shows different types of roundabouts and whether it meets transit needs.[4]

Table 1: Comparison of common roundabout features across types.

Roundabout Feature	Mini-Roundabout	Compact Roundabout	Single-lane Roundabout	Multilane Roundabout
Meets bus operations needs for 40' - 60' coaches?	No	Yes, for 40' coaches with proper design	Yes, with proper design	Yes, with proper design
Central island	Requires large vehicles to traverse central island, which is not feasible for buses	Requires vehicles longer than 40' to traverse central island	Non-traversable, but typically includes truck apron	Non-traversable, but typically includes truck apron
WSDOT Inscribed Circle Diameter (ICD) range	45 ft to 80 ft	65 ft to 120 ft	80 ft to 150 ft	120 ft to 165 ft
Maximum number of circulating lanes conflicting with each entry	1	1+	1	2+

Additional information available in *NCHRP 1043: Guide for Roundabouts*

- 2.3.1 Roundabout Characteristics and Applications: Roundabout Types
- 2.3.2 Roundabouts with Traversable Elements

[4] Adapted from NCHRP 1043, WSDOT Design Manual Exhibit 1320-1

3.2 Involve Metro Early

Engage with Metro early if a proposed roundabout is on a current or future transit route, including during planning studies, alternatives identification, and evaluation. Performance goals and outcomes related to transit can influence a project even before project design begins. Early engagement will help ensure that a roundabout can successfully be designed for buses as a project evolves from preliminary to final design.

Metro hopes project goals and desired outcomes include safe and reliable transit operations and improved access to bus stops. When differentiating between *accommodating* and *designing* for a large vehicle, Metro emphasizes that roundabouts on transit routes should be *designed* with transit in mind. Specifically, the Metro-specific bus should be used as a *design vehicle,* representing a large vehicle that regularly uses the facility and must stay on the roadway, rather than accommodating the bus through expecting it to traverse the center island or mount a truck apron.

Metro is interested in collaborating with jurisdictions throughout, especially in the areas highlighted in the iterative performance-based approach outlined in NCHRP 1043 Chapter 3 (Figure 1). Metro understands that while the NCHRP guidance provides valuable insight, each jurisdiction may have their own process. Furthermore, given WSDOT's role and their expertise with roundabouts, most jurisdictions across the state will consult WSDOT's design manual before turning to the NCHRP resources.

Additional information available in *NCHRP 1043: Guide for Roundabouts*

- 3.1 A Performance-Based Planning and Design Approach: Ties to the Project Development Process
- 3.3 Performance Measures
- 3.4 Decision-Making Framework
- 6.4 Intersection Control Evaluation: Project Considerations
- 9.1 Geometric Design Process and Performance Checks: Design Process
- 10.3.1 Horizontal Design Performance Influences: Roundabout Size and Shape

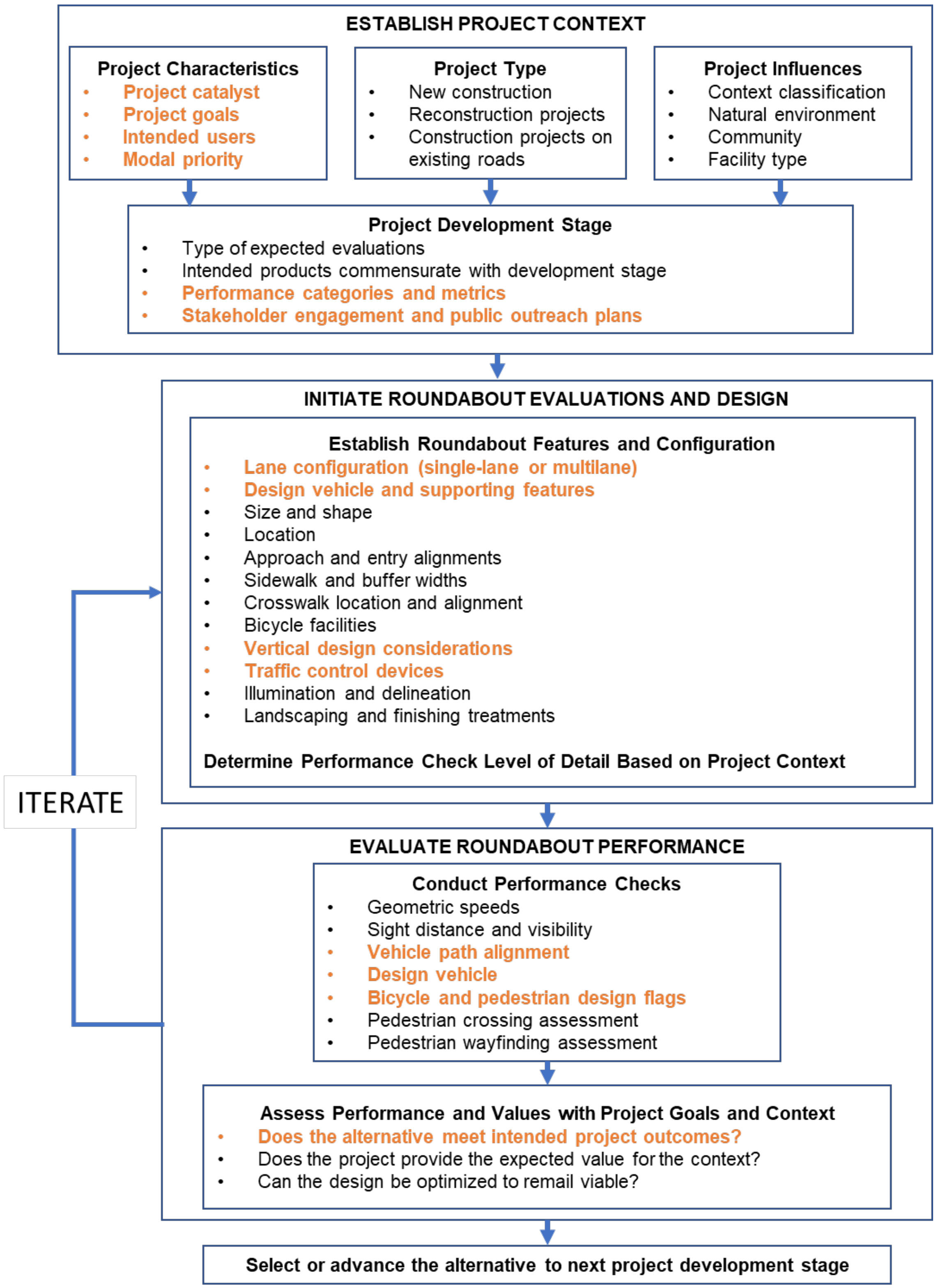


Figure 1: Roundabout design process (source: NCHRP 1043 Section 9.1). Metro areas of interest shown in **bold orange.**

4 Vehicle Characteristics and Street Design

This section includes guidance on transit design elements, both for the buses and people accessing the buses by foot or bike. Design elements should be considered in addition to those required by the design jurisdiction. Metro operates both 40-foot and 60-foot motorcoaches on bus routes in King County.

4.1 The Metro Bus as the Design Vehicle

As described in Section 4.4.4 of NCHRP 1043, transit buses may include fixed chassis and articulated vehicles. They can have a variety of wheelbase lengths as well as different distances between the bumpers and the outermost axles. These factors affect the swept path of the bus and potentially impact areas beyond the curb, such as signs, poles, and other fixed objects. Vehicle turning path modeling software, such as AutoTURN, developed by Transoft Solutions and preferred by Metro, can verify swept path and vertical clearance for Metro buses.

Use Metro's custom design vehicles in vehicle maneuver software: Metro developed custom AutoTURN vehicle templates and settings after finding that the national AASHTO bus design vehicles, the BUS-40 and BUS-45, do not match the specifications of Metro coaches. When designing horizontal and vertical curves, Metro requires using the custom AutoTURN settings with bicycle rack and side mirror clearance outlined in Metro's Transit Facilities Guidelines, Chapter 3.3: AutoTURN. Controlling speed is very important for Metro operations and it is important that it be emphasized during the design process. Analyze turning movements with buses maintaining a 5-10 mph speed throughout the roundabout. Figure 2 shows parameters at the time this guidance were published.

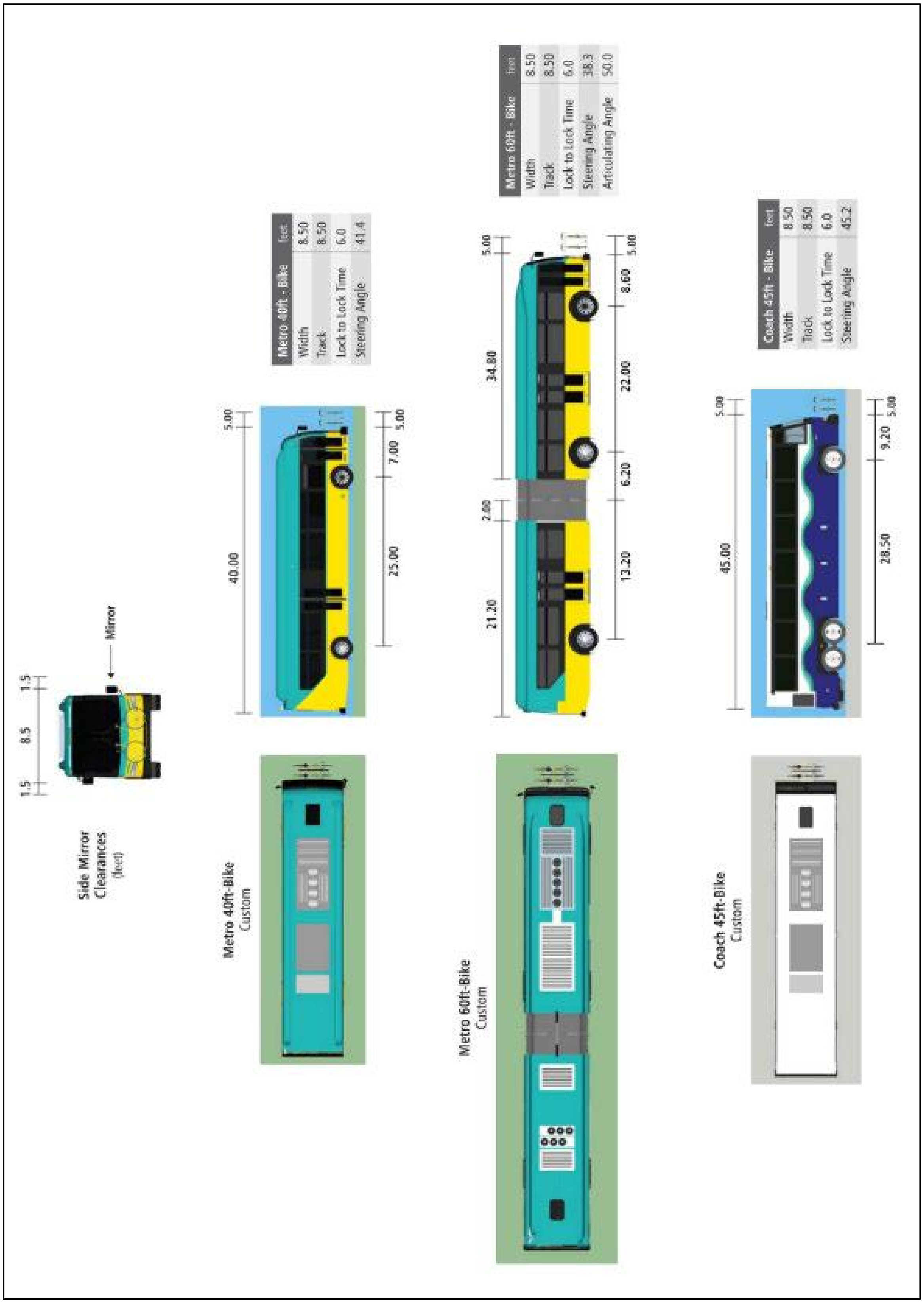


Figure 2: AutoTURN Vehicle Modifications with Deployed Bike Racks

Buses should not need to use truck aprons: The roundabout circulatory roadway should be designed to avoid having a Metro bus track over the truck apron, which could jostle bus occupants. Metro's bus fleet includes many 60-foot articulated buses in addition to the more typical 40-foot bus, therefore both vehicle types should be tested in AutoTURN or a similar vehicle maneuver software[5]. Metro encourages the use of truck apron designs that will allow for occasional and incidental use by buses without disturbing passengers (see section 4.7: Curb and Truck Apron Design).

Additional information available in *NCHRP 1043: Guide for Roundabouts*

- 4.4 User Considerations: Large Vehicles
- 4.4.1 Designing for Versus Accommodating Large Vehicles
- 4.4.4 Buses
- 10.3.3 Roundabout Approach Alignment
- 10.5 Design for Large Trucks
- 11.6 Trucks
- 13.4 Curb and Pavement Details: Curb Type
- A.4 Design Performance Check Techniques: Design Vehicle

Additional information available in *Transit Route Facilities Guidelines*

- 3.1 Metro Fleet
- 3.2.2 Street Widths
- 3.3 AutoTURN
- Appendix B: Metro Bus Design Specifications

4.2 Multilane Roundabouts

For multilane roundabouts, designers should work with Metro during sketch design to decide if buses will operate by straddling the lane (also known as lane splitting) or staying within the lane. Based on NCHRP 1043 recommendations, Metro believes an optimal bus design approach established early in project planning in coordination with Metro staff will provide the most functional roundabouts. NCHRP 1043 Section 7.2.4 discusses trade-offs between designs to stay in lane and designs to split lanes for large vehicles. Metro's preference, however, is to be able to stay in lane whenever possible to minimize transit delay and incidence of low-speed, sideswipe crashes.

Transit operators are required to qualify on a particular route before they can drive the route themselves. During route qualification, operators receive training on specific characteristics and techniques for driving the route safely and efficiently. When a route includes a roundabout, instructions for navigating the roundabout will be provided as part

[5] A 60-foot articulated bus can make a tighter turn than a 40-foot bus, but the trailing end tends to pull a straight line through the roundabout, leading to potential adjacent lane incursions and possible curb strikes on entry or exit, even if the central truck apron is cleared.

of the route qualification process, including instructions about whether to stay in lane or split lanes while traversing the roundabout.

Lane width considerations: Metro's Transit Route Facilities Guidelines Section 3.2.2 calls for 11-foot minimum lanes to accommodate turning movements for buses and to prevent them from encroaching into the adjacent lane. This minimum width applies to roundabout approaches but does not apply to the circulating area. NCHRP 1043 Section 4.4 notes that the swept path of the truck or bus may be the critical design dimension. It also notes that, "designing all movements for the largest possible truck can lead to negative safety and operational performance issues for other roundabout users, particularly people walking and biking. Practitioners need to configure roundabouts to best serve large vehicles without sacrificing the safety performance and comfort levels of other users."

Designing for in-lane roundabouts: Metro prefers that operators stay in lane as this is consistent with Metro operational guidance and offers the optimal speed and reliability benefits for transit. However, Metro acknowledges that there are tradeoffs for in-lane operations when considering all roadway users. In-lane designs for large vehicles like buses typically result in a larger overall roundabout radii and wider lanes, which increases speeds and requires a larger footprint for the roundabout.

In-lane designs that do not accommodate the Metro design vehicle specified in Figure 2 can result in a bus over-tracking into other lanes, which may create conflicts with other vehicles in the roundabout.

Designing for lane splitting: Splitting or straddling lanes is considered a non-standard movement for Metro operations. In places with high pedestrian volumes or other design constraints, Metro may support roundabouts designed for lane splitting due to lower operating speeds. Instructions for splitting lanes will need to be included in the operator route qualification process and may require additional operator training materials (e.g., diagrams or videos).

NCHRP 1043 guidance for straddling lanes is mixed. Authors advise to design for trucks to straddle lanes in most situations, as research suggests truck drivers do not attempt stay in lane. However, Section 10.5.3 notes that a transit agency may necessitate accommodating buses within their own lane to travel adjacent to a passenger car in places with frequent bus service as shown below.

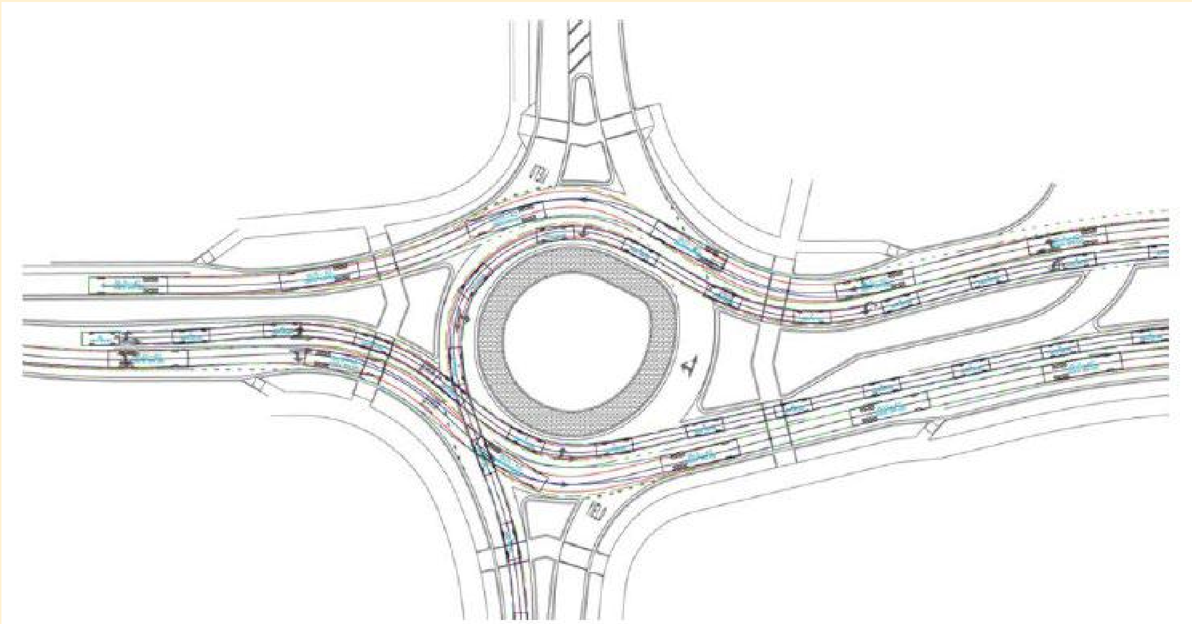


Figure 3: Example of side-by-side navigation for bus travelling straight and passenger car. (Source: NCHRP 1043, Kittelson & Associates)

For straddle-lane design, trucks and buses occupy more than one lane, meaning no vertical lane separation can be included in the entrance, circulating lanes, and exiting. Therefore, one objective for straddle-lane design becomes maintaining lane discipline for passenger cars (i.e., preventing lane drift) by achieving path alignment for passenger cars. Obtaining acceptable view angles is a related second objective. These two objectives require vehicles to be staggered at the entrance so vehicles in the outside lane can see in front of the vehicle in the adjacent lane to the left.

Additional information available in *NCHRP 1043: Guide for Roundabouts*

- 2.3.4 Roundabout Categories: Multilane roundabouts
- 7.2.2 Safety Performance Analysis: Conflict Points at Multilane Roundabouts
- 7.2.3 Conflict Types and Conflict Points: Trucks
- 7.5 Safety Surrogate Measures
- 9.7.1 Types of Design Vehicle Checks
- 9.7.2 Evaluating Design Vehicle and Check Vehicle
- 10.5.3 Design Vehicles in Multilane Roundabouts
- 10.7.5 Principles and Techniques for Straddle-Lane Design
- 10.7.6 Techniques for Designing for Trucks Staying In-Lane
- 12.2.4 Lane Designations for Multilane Roundabouts

4.3 Bus Stops

Bus stop placement may vary for each roundabout project in response to several factors, including the number of lanes, site topography, transit service design, locations of popular pedestrian destinations, and the surrounding pedestrian sidewalk network.

Bus stop placement should optimize safety, accessibility, and transit operations: Jurisdiction partners should reach out to Metro early in the planning phase to determine which locations best support the following transit needs:

- Near-side or Far-side: Avoid in-lane near-side stops at multilane roundabouts (see page 15). Metro prefers near-side stops at single-lane roundabouts to reduce the risk of passenger falls, as passengers intending to exit at the next stop often begin standing up while the coach is still navigating the roundabout.
- Access: Bus stops sited closer to intersections usually reduce walking distances. Consider out-of-direction travel and the number of crossings to access high-demand destinations or to transfer between routes, if possible. Account for increased pedestrian volumes near future transit stations and mobility hubs.
- Operations: Metro prefers in-lane stops as described in Metro's Transit Route Facilities Guidelines (Chapter 3) because they improve transit travel times and reduce delays to transit vehicles. When traffic volumes are high, a bus operator in a pull-out is forced to wait to re-enter the travel lane.

Metro prefers near-side in-lane stops in single lane roundabouts and far-side in-lane stops in multilane roundabouts. Location, context, and pedestrian travel patterns will influence final bus stop siting and design.

Bus stop pull-outs: On a multilane roundabout, a bus pull-out is appropriate when a near-side stop best fits the context. In this case or others where a pull-out is under consideration, Metro and partner agencies have used the following criteria (in addition to national guidelines):

- Metro will request a gap analysis to estimate wait times.
- Include an evaluation of sight distances and design tapers for bus operators to safely merge back into the travel lane.
- Design must accommodate bus space based on need. For example, a stop may need to accommodate two 60-foot articulated coaches, each with bike racks deployed.
- For the front coach, the distance from the face of curb on the platform to each of the doors shall be within 6 inches.
- For a second coach, the front door shall be within 6 inches horizontally from the face of curb on the platform. If the back doors of the second coach are more than the desirable 6 inches away from the platform, they shall be at least 18 inches away to allow for a safe space for passengers to step off the coach.
- Coaches shall be fully within the bus pull-out when docking.

Designers can refer to National guidance in NCHRP 1043 Section 10.13 (p 10-95) for further details. It is consistent with Metro's preferences, except Metro has a strong preference for in-lane stops:

To provide the best quality service for bus passengers, bus stops are located as close to pedestrian crossings as possible to minimize out-of-direction travel.

If a bus stop on the entry side of the roundabout (a near-side stop) is chosen, it will be located and designed as follows:

- *On a single-lane approach, the bus stop could be in the travel lane immediately upstream of the pedestrian crossing.*
- *On a multilane approach, a near-side bus stop in the travel lane is to be avoided because vehicles in the lane next to the bus may not see pedestrians and create a multiple-threat condition. [NCHRP 1043 identifies that] a pull-out compatible with the pedestrian and bicycle circulation system is instead used. However, a bus exiting the pull-out may obscure the visibility between pedestrians and oncoming motor vehicles; a bus stop on the exit side may be preferable.*

Because Metro uses in-lane stops, Metro prefers far-side stops on multilane roundabouts.

If a bus stop on the exit side of the roundabout (a far-side stop) is chosen, it will be located and designed as follows:

- *Bus stops are located immediately beyond the pedestrian crossing to improve visibility of pedestrians to other exiting vehicles. Proximity to the crosswalk is preferable to minimize out-of-direction travel for pedestrians.*
- *Stops on the exit side result in the crosswalk being behind the bus, which helps drivers see pedestrians and allows the bus to depart while pedestrians are still crossing the street.*
- *Bus pull-outs reduce the likelihood of queuing behind the bus into the roundabout. A bus pull-out may create sight line challenges for the bus driver to see vehicles approaching from behind as the bus driver attempts to merge into traffic.*

Metro uses in-lane stops because bus pull-outs cause transit delay.

Bus stops cannot be located along the circulatory roadway for the following reasons:

- *Bus stops along the circulatory roadway eliminate the detectable buffer that is required between the circulatory roadway and pedestrian path per proposed PROWAG. Detectable buffers are discussed further in Section 10.4.*
- *Bus stops within the circulatory roadway, either in-lane or in a pull-out, introduce conflicts within the circulatory roadway that cannot be present at a roundabout.*

Additional information available in *NCHRP 1043: Guide for Roundabouts*

- 10.13 Bus Stop Placement

Applicable information available *Transit Route Facilities Guidelines*

- 3.2.3 Bus Stop Lengths and Distances from Intersections
- 3.2.4 In-Lane Stops
- 3.2.5 Bus Pull-Outs
- 3.4 Sight Distance
- Chapter 4: Bus Stop Guidelines
- Chapter 5: Bus Stop Elements

4.4 Raised Crossings and Other Vertical Clearance Considerations

Raised pedestrian crossings are occasionally designed for roundabouts and other intersections to encourage slower speeds and prioritize pedestrian safety. Furthermore, adopted PROWAG requires a raised crossing and/or a traffic control device at a multilane roundabout crossing[6]. Raised crossings must provide ample clearance for buses to successfully traverse the crossing without damaging the coach.

"Public Rights-of-Way Accessibility Guidelines, as amended for shared-use paths, require pedestrian-activated signals with accessible pedestrian signals at multilane roundabout crossings and multilane channelized turn lanes and/or a raised crosswalk. Common active traffic control devices at roundabout crossings include:

- ***Rectangular rapid-flashing beacons.** As an active warning device, the RRFB rests in dark when not used and flashes for a predetermined time upon activation by the crossing user. These devices can be mounted along the roadside, overhead, or both…*
- ***Pedestrian hybrid beacons.** This device also rests in dark when not used and follows MUTCD guidelines for signal placement."* (NCHRP 1043 Section 12.3.3)

Use Vehicle Maneuver Software such as AutoTURN to test bus vertical clearance at raised crossings: Metro uses customized AutoTURN settings to test the clearances of raised crossings. Design constraints for raised crossings including design speed of buses at the location of the crossing, type of buses (see AutoTURN requirements), and a controlling factor of 4" minimum clearance between the bottom of the bus to any impediment. Buses modeled in AutoTURN do not account for a bus full of riders, which can weigh down the bus during turns and reduce clearance. As a result, designers should ensure that the minimum clearance is maintained during all turn movements.

[6] PROWAG, published in 2023, represents best practice but requires USDOT adoption before being enforceable. The Manual of Traffic Control Devices (MUTCD) 11th Edition, also published in 2023, does not identify this requirement. States have two years to either adopt the MUTCD or release a supplement or their own local version.

"Raised crosswalks or speed humps force drivers to slow down; lower speeds have been linked to increased yielding behavior. A raised crosswalk can also guide pedestrians who are blind or have low vision to stay within the crosswalk if they can detect the crosswalk's side slopes as boundaries. The design of a raised crosswalk is a balance of a steep slope with a modest run (which may result in significant speed reductions) versus a gentler slope (which may have a more modest speed reduction but retain a higher capacity). Crosswalk design will also consider design vehicle maneuverability and needs." (NCHRP 1043 Section 10.4.7)

Figure 4: Example of a raised crosswalk at a multilane roundabout (source: NCHRP 1043, Jonathan French). AutoTurn Vertical Clearance Analysis should show minimum 4" clearance for the Metro bus.

Check vertical clearance at other locations: As part of profile and cross-section development, practitioners need to provide Metro with checks for adequate ground clearances at the locations shown in the following figure.

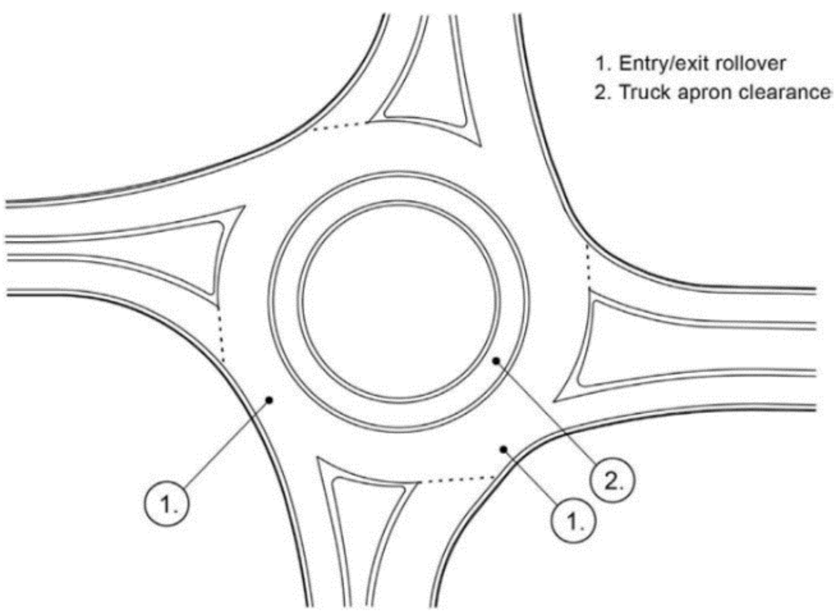


Figure 5: Typical ground clearance concern locations. (Source: NCHRP 1043, Adapted from Wisconsin Department of Transportation.)

Additional information available in *NCHRP 1043: Guide for Roundabouts*

- 7.2.4 Conflict Types and Conflict Points: Pedestrians
- 7.5.1 Safe System for Intersection Methods
- 9.8 Bicycle and Pedestrian Wayfinding and Crossing Assessment
- 10.3.4 Facilities for Pedestrians and Bicyclists
- 10.4 Design for People Walking and Biking
- 10.9.4 Pedestrian and Bicycle Crossings for Bypass Lanes
- 11.5 Pedestrian Design Influences
- 11.6 Vertical Alignment and Cross-Section Design: Trucks
- 12.3 Traffic Control Devices and Applications: Entry Area
- A.5 Bicycle and Pedestrian Design Flags
- A.6 Pedestrian Crossing Assessment
- A.7 Pedestrian Wayfinding Assessment

Additional information available in *Transit Route Facilities Guidelines*

- 3.3 AutoTURN

Other Reports and Guidance

- NCHRP Research Report 948: Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges.
- NCHRP Research Report 834: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities: A Guidebook.
- U.S. Access Board's *Public Right-of-Way Accessibility Guidelines* (PROWAG), published August 2023.

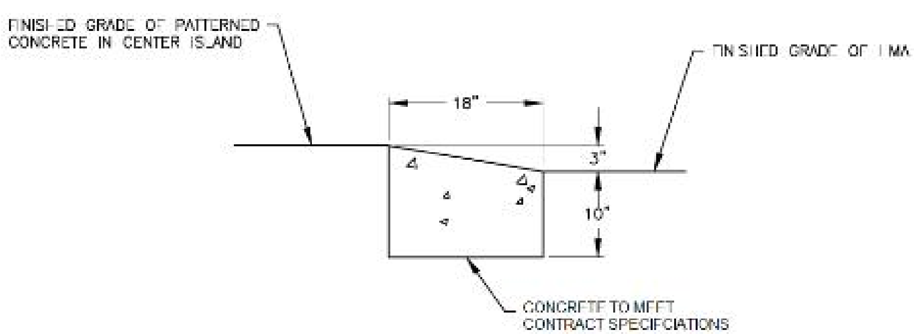
5 Curb and Truck Apron Design

Curb and truck apron design plays a large role in determining whether a bus can successfully navigate a roundabout.

Avoid roundabout designs that require buses to traverse the center island or mount truck aprons: Avoid using roundabouts on bus routes if buses need to traverse the center island or mount the truck apron. As cited in NCHRP 1043, when coaches roll over these features it can jostle passengers out of their seats or mobility devices or cause standing passengers to fall. Roundabout designs that require the bus to use truck aprons should include design documentation demonstrating why Metro's preferred design is unfeasible.

Use a linear curb for truck aprons: If a bus must use a truck apron due to space requirements (e.g., adjacent buildings or right-of-way do not allow expanding the roundabout), Metro has found that a 6:1 linear curb is acceptable. Metro has implemented this modified curb design in King County and found it acceptable based on operator feedback, field observations, and field tests with King County Road Services.

WSDOT updated its truck apron design detail in 2022 from a rolled curb to a straight curb with a 4:1 ratio.[7] Metro staff tested buses on WSDOT's pre-2022 typical mountable curb with a rolled curb transition, and concluded it is not preferred as it is an uncomfortable ride for passengers, can potentially damage Metro buses, and may increase bus maintenance. Metro has not yet tested the updated WDSOT standard design of a 4:1 linear curb.



ROUNDABOUT CENTER ISLAND SLOPED
CEMENT CONCRETE CURB
NTS

Figure 6: Preferred center island has a 6:1 sloped curb.

[7] WSDOT Design Manual & Standard Plan F-10.18-03, updated Mar 28, 2022, https://wsdot.wa.gov/engineering-standards/all-manuals-and-standards/standard-plans).

5.1 Coach Testing for Roundabout Design

Following partnerships with Sound Transit and WSDOT, Metro is open to partnering with other agencies and local jurisdictions to run coach testing on roundabout designs when the project can fund this activity. Previous partnerships to refine the curvature of new roundabouts have led to successful designs on N 145th Street, and at the I-405/NE 85th Interchange. Designers and planners should discuss this possibility as early as feasible when there are enough details to provide a preliminary layout for the roundabout and have a constructive conversation. The images below show an aerial view of the King County test facility for the NE 85th Interchange and in-lane BRT station project.

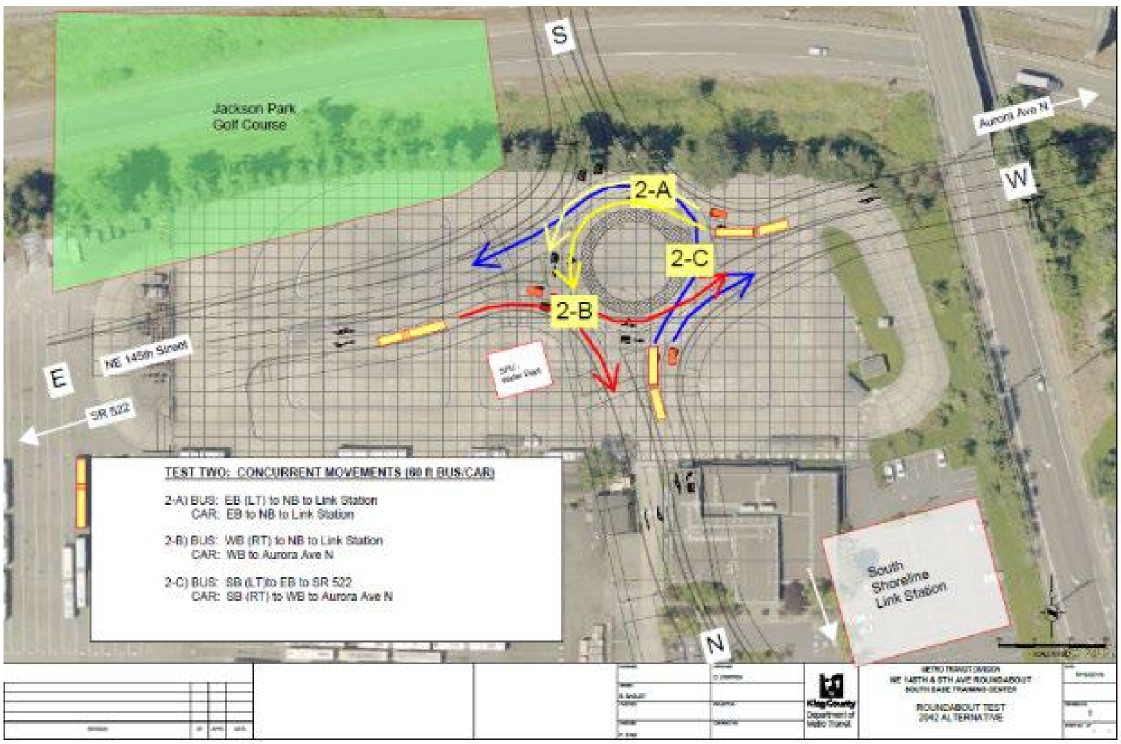


Figure 7: Notes from a coach test of the N 145th Street roundabout design.

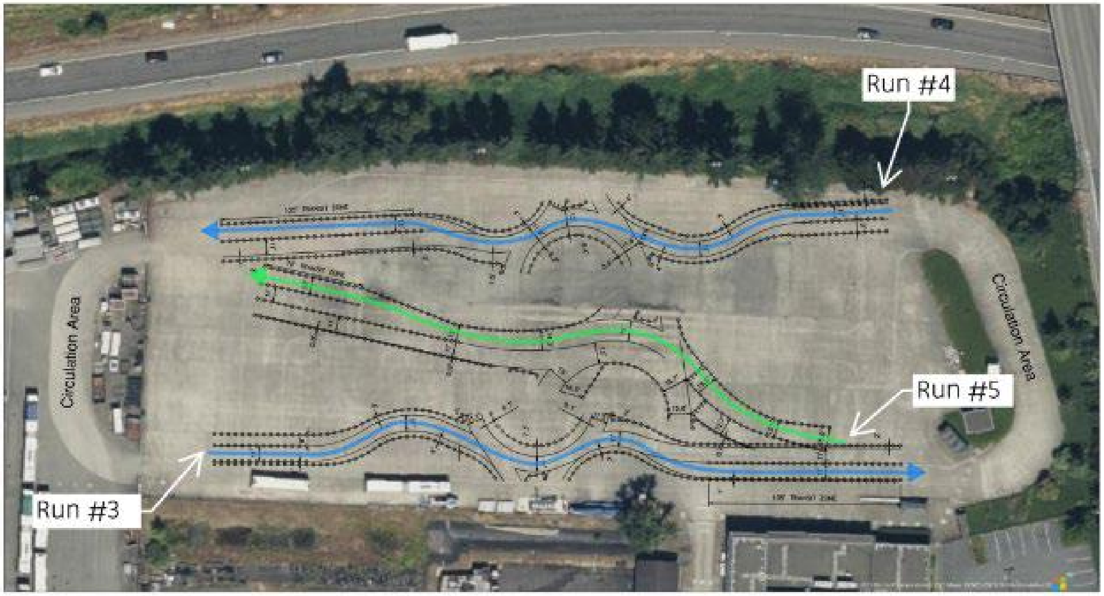


Figure 8: Layout for coach testing of the I-405/North 85th Interchange roundabout design.

60-foot coach docked at head of bus stop zone

40-foot coach navigating the roundabout

Figure 9: Buses navigating the I-405/North 85th Interchange proposed roundabout design.

Transit Priority Treatments and Operational Performance Analysis for Transit

As described in Metro's Speed and Reliability Guidelines and Strategies, Metro regularly applies treatments at signalized intersections such as queue jumps or transit signal priority. Incorporating these treatments into a roundabout can be challenging. The roundabout itself could be considered a transit improvement if it reduces bus delay or improves headway adherence compared to existing or alternative intersection treatments, but transit priority treatments may be required depending on FTA or agency rules.[8]

[8] Transit without priority treatment at roundabouts does not meet FTA's New Starts grant program criteria for Bus Rapid Transit to "provide faster passenger travel times through congested intersections by using active signal priority in separated guideway, and either queue-jump lanes or active signal priority in nonseparated guideway."

High-capacity routes like RapidRide require extra considerations: Roadways in King County that accommodate bus rapid transit, including Metro's RapidRide and Sound Transit's Stride, or other frequent transit service require careful evaluation to determine appropriateness of roundabouts. If a roundabout is present or proposed on a roadway, treatments such as queue jumps with metering signals may be necessary to meet the transit priority and reliability expectations on such routes.

Queue bypass lanes can provide transit priority at roundabouts: These lanes are assumed to be effective treatments at high volume roundabouts because they ensure that transit coaches can approach and depart the roundabout without being hindered by other traffic. Metro will request queue bypass lanes at roundabouts on frequent transit routes, such as the planned roundabout with the queue bypass at NE 145th St and 5th Ave N near the Shoreline South/148th Link light rail station, and is interested in engaging with our partners in studying the effectiveness of this treatment.

Consider metering or signalizing a roundabout for transit signal priority: Traffic signals or meters at roundabouts are uncommon, as roundabouts are usually designed to operate with yield control at the entries. However, if analysis indicates buses on high-capacity transit routes may struggle finding gaps, or if the agency considers signals for other reasons, transit signal priority should be analyzed.

Transit delay, queue length, bus wait time serve as key operational performance indicators for transit: Unlike at signalized intersections, queues at roundabouts tend to move continuously and are typically shorter in length than for signalized or stop-controlled movements. Consequently, transit delays at roundabouts may be less than at signals. To assess any potential negative impacts, Metro may request estimates of delay and queue lengths for bus movements. These queue lengths should inform the necessity and length of any queue bypass lanes. When considering a pull-out stop, it is critical to account for the time a bus operator must wait to find a gap to pull back into the travel lane.

Additional information available in *NCHRP 1043: Guide for Roundabouts*

- 8.3.4 Operational Performance: Queue length
- 12.6 Entry Metering Signals

Appendix A Abbreviations, Acronyms and Definitions

AHJ	Authorities having jurisdiction – the city, county, or state Department of Transportation that has authority on the road design and operations
BAT lane	Business access and transit lane. Lanes can only be used by transit and general purpose right turns at intersections or driveways.
Bus only lane	Continuous lane restricted to buses only. If right turns are allowed from the lane at intersections, it is considered a BAT lane.
DOT	Department of Transportation
Downstream	The direction to which the transportation flow is moving towards
The Guide	*NCHRP Report 1043: Guide for Roundabouts*
Far-side	The side of an intersection after the bus travels through the intersection
Headway	Time interval between buses moving in the same direction on the same route
HCM	*Highway Capacity Manual*
ICD	Inscribed circle diameter
In-lane stop	A stop that is in the lane. This removes delay and increases reliability because it removes both the pull-out time and traffic re-entry time.
Near-side	The side of an intersection before the bus crosses
MUTCD	*Manual on Uniform Traffic Control Devices for Streets and Highways*
NACTO	National Association of City Transportation Officials
NCHRP	National Cooperative Highway Research Program
PROWAG	Public Right-of-Way Accessibility Guidelines, published by the US Access Board
Pull-out	A designated spot on the side of a road where buses pull out of the flow of traffic to pick up or drop off passengers. Pull-outs increase bus delay due to the cost of time necessary to merge back into flowing traffic.
Queue bypass lane	A bus-only lane intended for transit vehicles to bypass a point of recurring traffic congestion. Often a treatment, such as a queue jump signal, is needed at the end of the queue bypass lane to help buses re-enter traffic.
RRFB	Rectangular rapid-flashing beacon
Traverse	To travel across the center island of the roundabout
US Access Board	An independent federal agency devoted to accessibility for people with disabilities
Upstream	The direction from which the bus or transportation flow is coming.
WSDOT	Washington State Department of Transportation

Appendix B Bibliography

Community Transit. (2014). *Designing Transit Friendly Roundabouts (Final Report)*.

King County Metro. (n.d.). *Schedules and maps*. https://kingcounty.gov/en/dept/metro/routes-and-service/schedules-and-maps. Retrieved May 2024.

King County Metro. (2021). *Speed and reliability guidelines and strategies*. https://kingcounty.gov/~/media/depts/metro/about/planning/speed-reliability-toolbox.pdf. Retrieved August 2023.

National Academies of Sciences, Engineering, and Medicine. (2023). *NCHRP Report 1043: Guide for Roundabouts*. The National Academies Press. https://doi.org/10.17226/27069. Retrieved August 2023.

National Academies of Sciences, Engineering, and Medicine. (2021). *NCHRP Research Report 948: Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges.* https://www.trb.org/Main/Blurbs/181781.aspx. Retrieved August 2023.

National Academies of Sciences, Engineering, and Medicine. (2017). *NCHRP Research Report 834: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities: A Guidebook*. https://nap.nationalacademies.org/download/24678. Retrieved August 2023.

U.S. Access Board. (2023). *Public Right-of-Way Accessibility Guidelines (PROWAG)*. https://www.access-board.gov/prowag/. Retrieved August 2023.

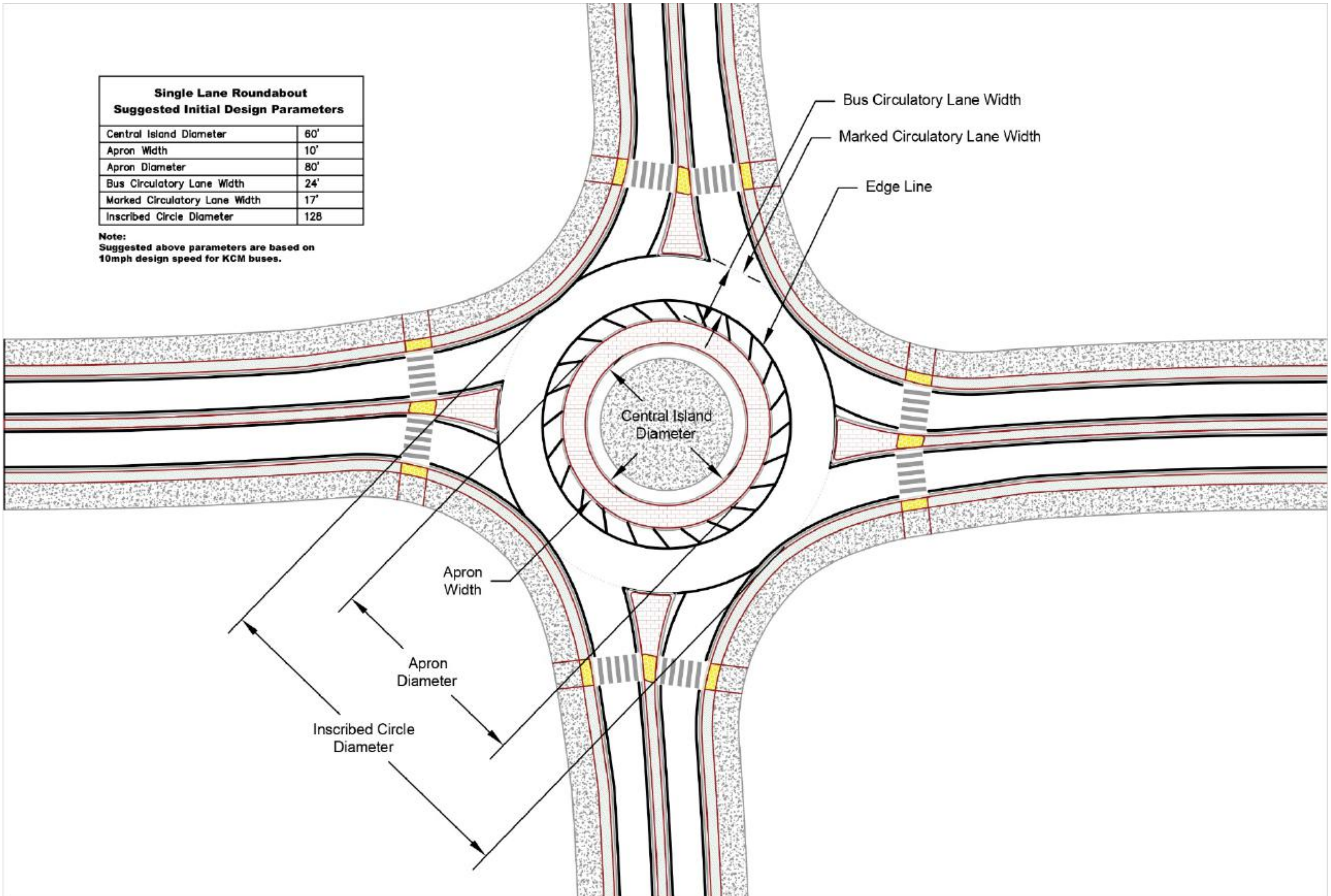
Washington State Department of Transportation. (2023). *Design Manual, Version M 22-01.22.* wsdot.wa.gov/publications/manuals/fulltext/M22-01/design.pdf. Retrieved October 2023.

Washington State Department of Transportation. (2021). *I-405, NE 85th Street Interchange and In-lane BRT Station Project's Request for Proposal*, 2.27.5.1.2 Bus Docking, 20210301 V1.

Appendix C Suggested Initial Design Parameters

The following diagrams highlight typical parameters for designing transit-friendly roundabouts. Although these parameters will likely be re-evaluated and adjusted during the full design process, these diagrams can provide a starting point for purposes of planning and establishing a footprint for a proposed roundabout.

As a new roundabout progresses into final design, designers should consult with Metro and use Vehicle Maneuvering Software such as AutoTURN to fine-tune designs; guidelines for using this software for typical Metro coaches are also provided in these diagrams.



Single Lane Roundabout
Suggested Initial Design Parameters

Central Island Diameter	60'
Apron Width	10'
Apron Diameter	80'
Bus Circulatory Lane Width	24'
Marked Circulatory Lane Width	17'
Inscribed Circle Diameter	128

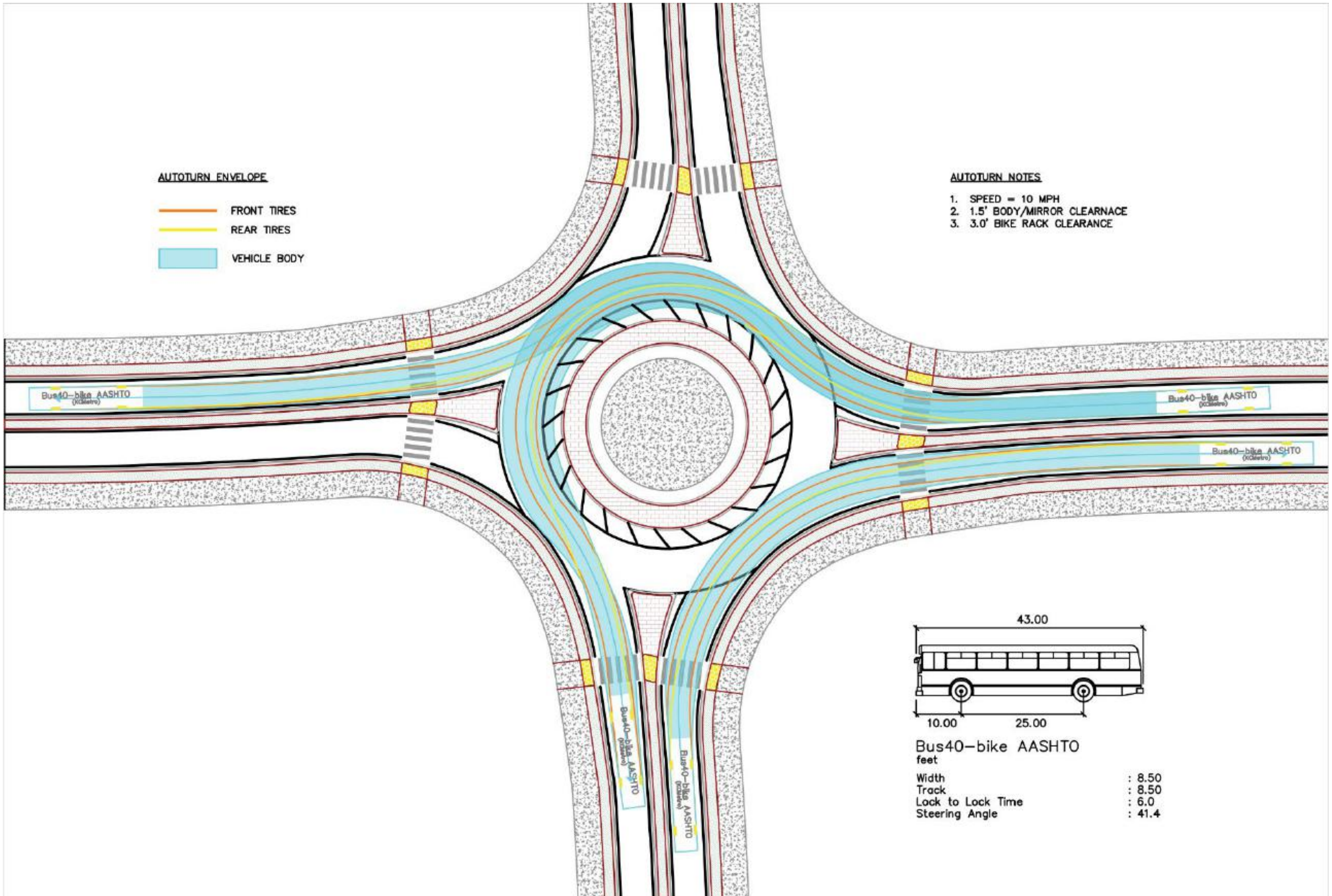
Note:
Suggested above parameters are based on 10mph design speed for KCM buses.

King County METRO

Figure 1:
Single Lane Roundabout Design Parameters

wsp

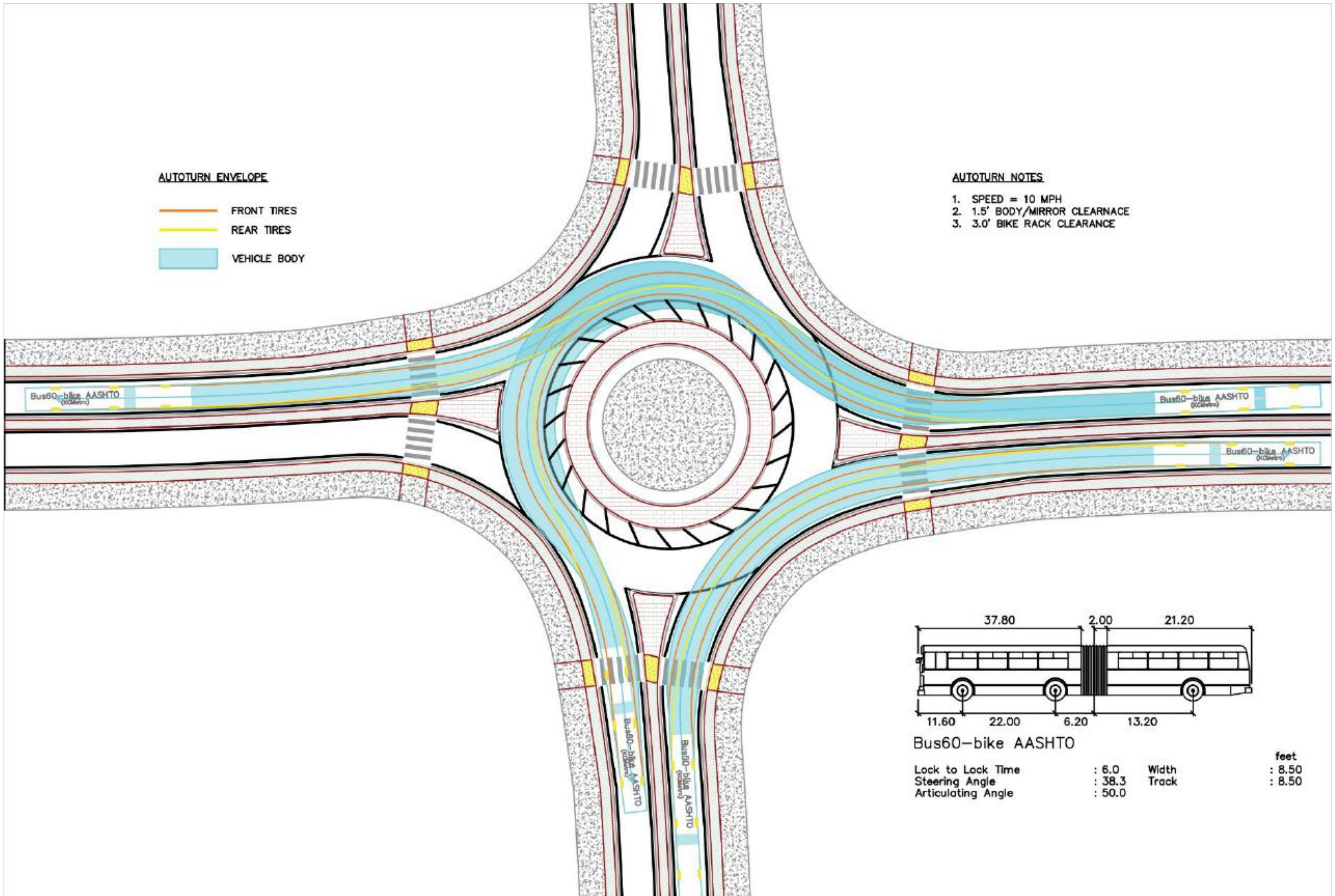
Date: February 2023



King County METRO

Figure 2:
Single Lane Roundabout AutoTurn Simulation
(KCM Bus40-Bike)

wsp
Date: February 2023

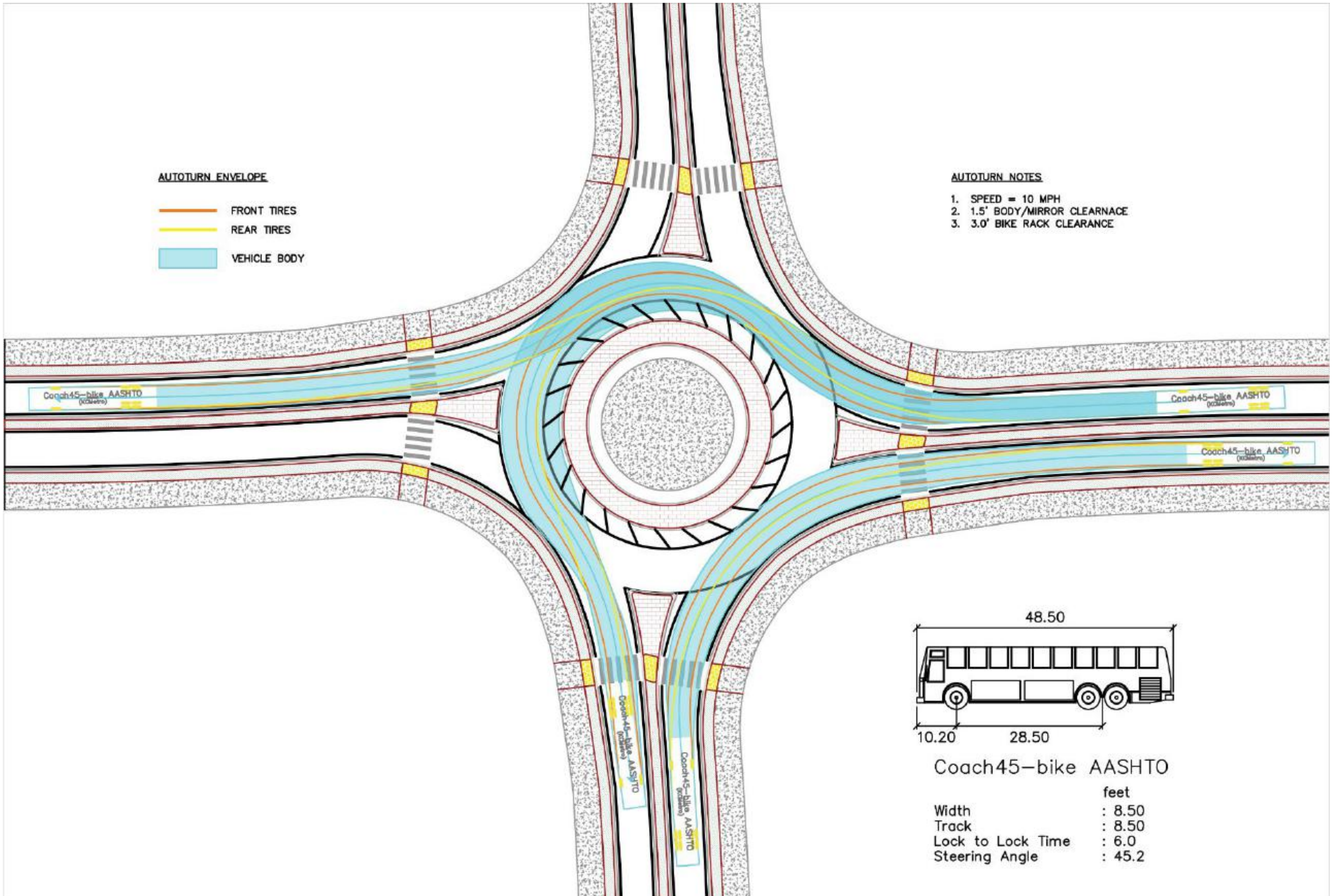


King County METRO

Figure 3:
Single Lane Roundabout AutoTurn Simulation
(KCM Bus60-Bike)

wsp

Date: February 2023



King County METRO

Figure 4:
Single Lane Roundabout AutoTurn Simulation
(KCM Coach45-Bike)

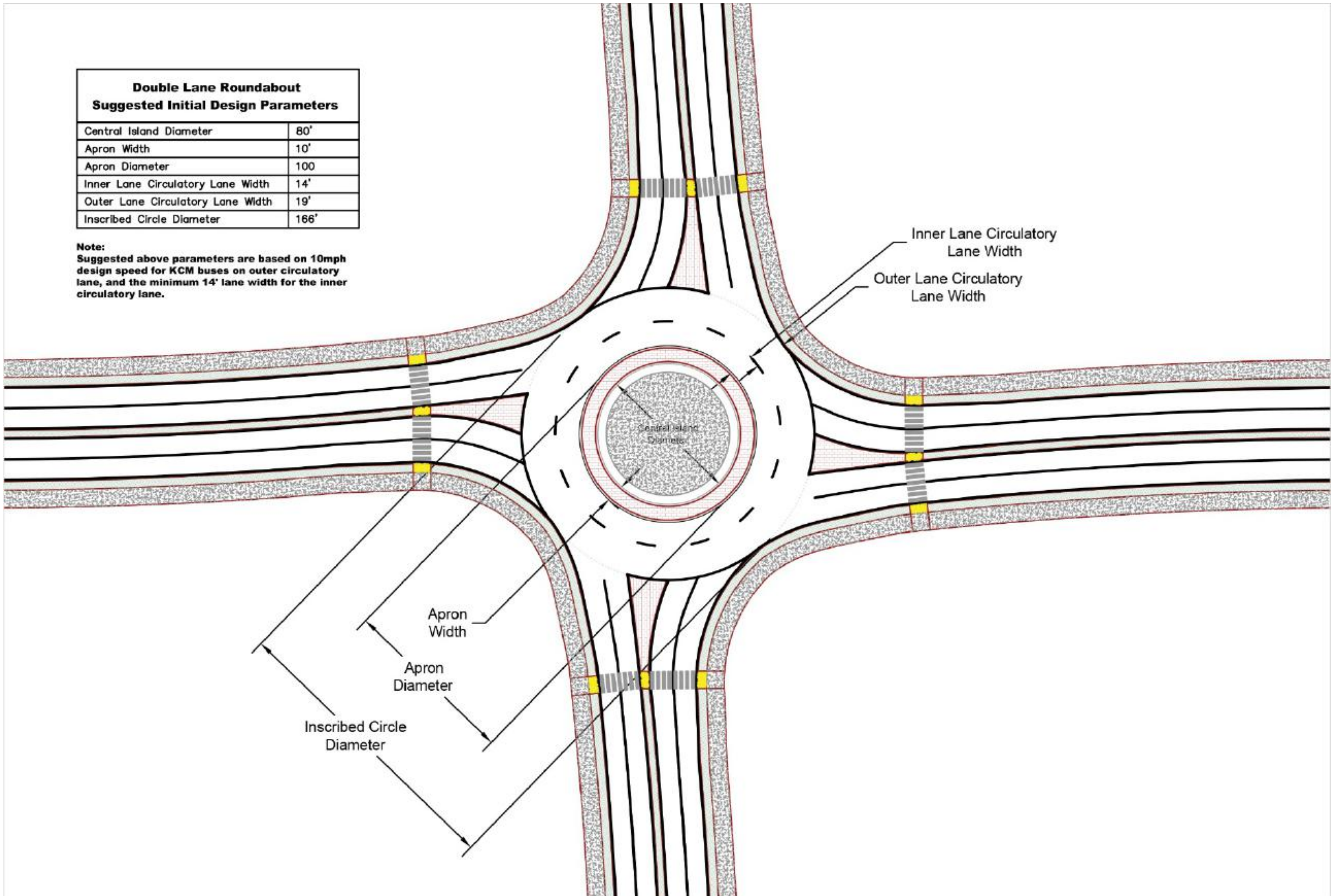
wsp

Date: February 2023

Double Lane Roundabout
Suggested Initial Design Parameters

Central Island Diameter	80'
Apron Width	10'
Apron Diameter	100
Inner Lane Circulatory Lane Width	14'
Outer Lane Circulatory Lane Width	19'
Inscribed Circle Diameter	166'

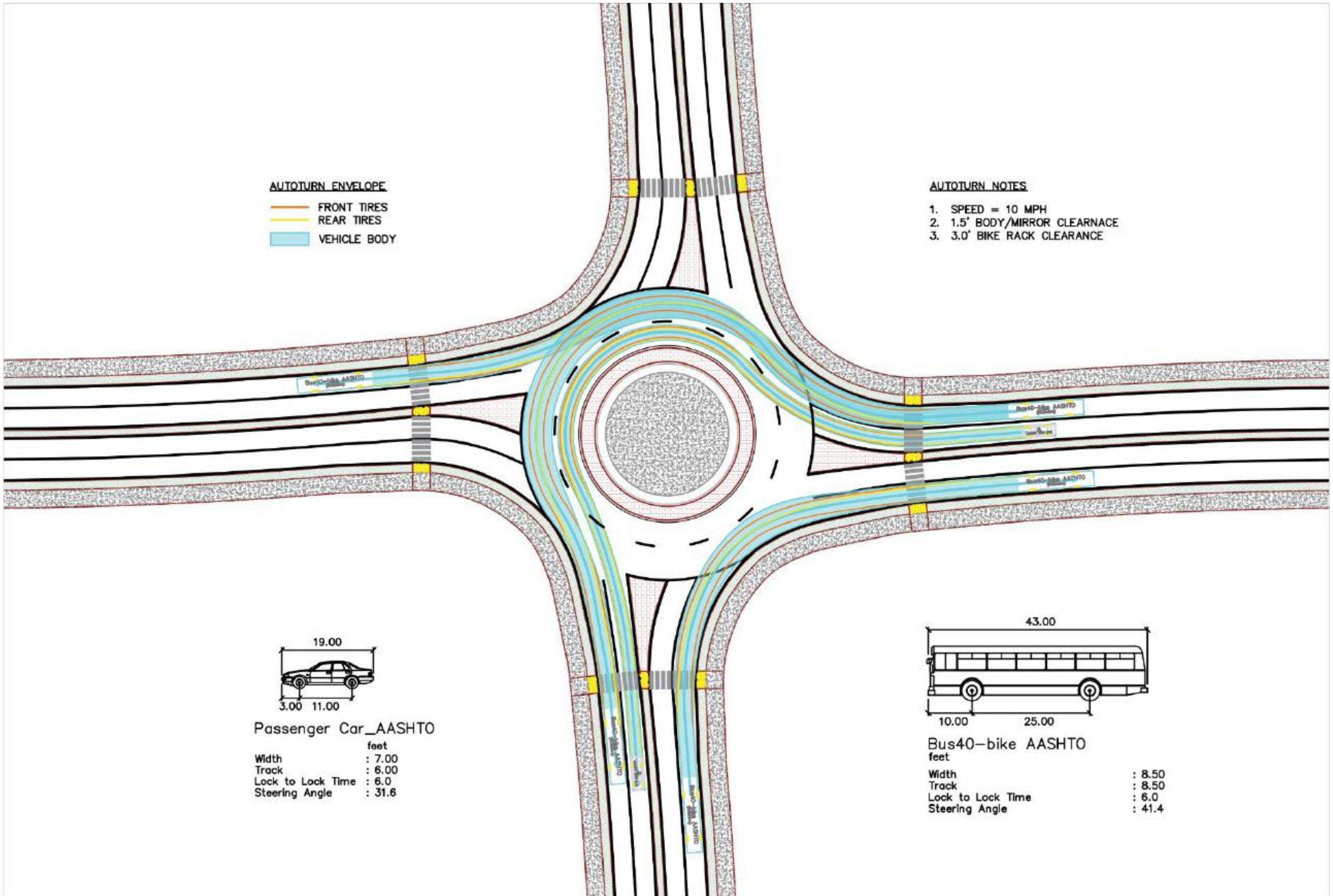
Note:
Suggested above parameters are based on 10mph design speed for KCM buses on outer circulatory lane, and the minimum 14' lane width for the inner circulatory lane.



King County METRO

Figure 5:
Double Lane Roundabout design Parameters

Date: February 2023

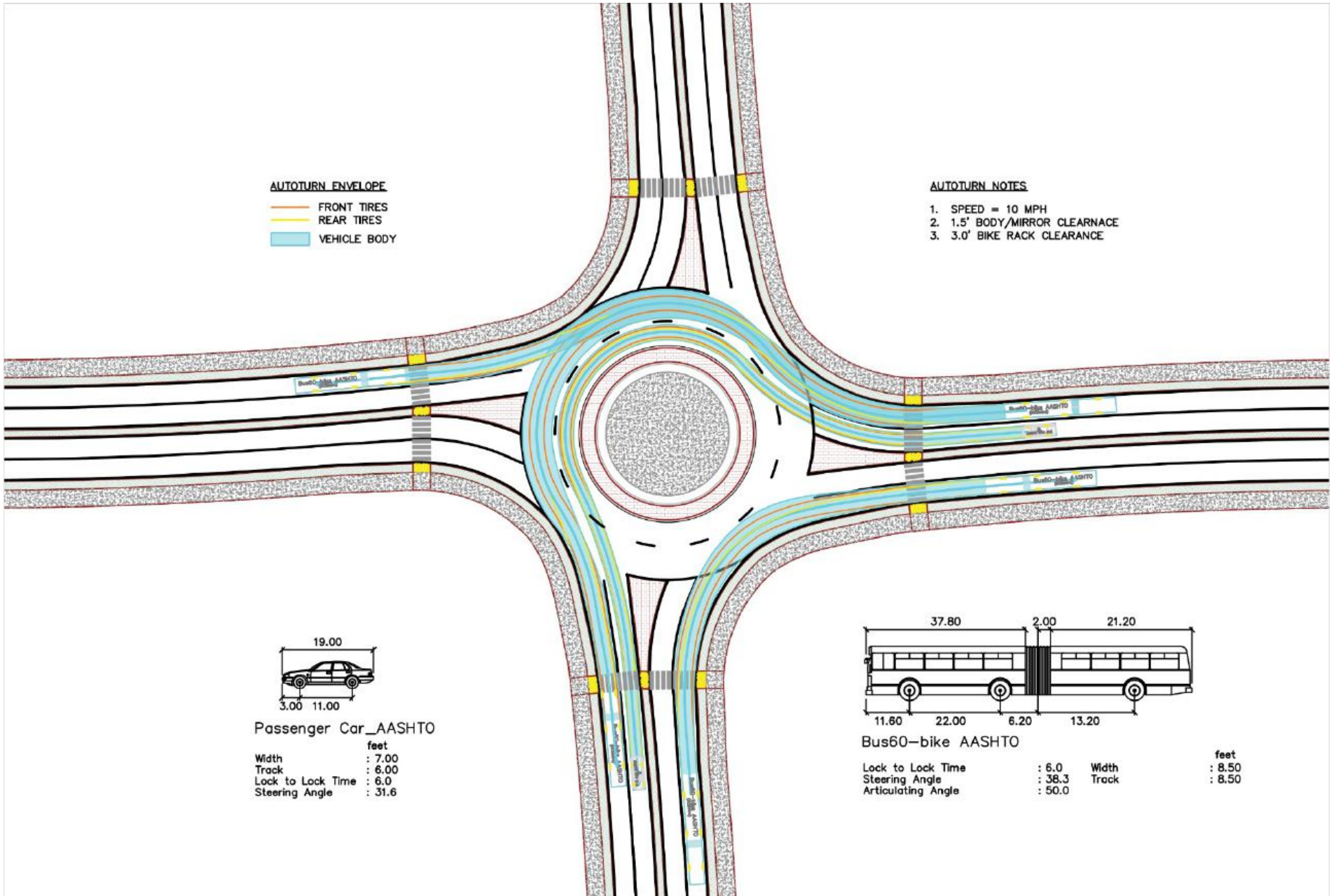


King County METRO

Figure 6:
Double Lane Roundabout AutoTurn Simulation
(KCM Bus40-Bike)

wsp

Date: February 2022

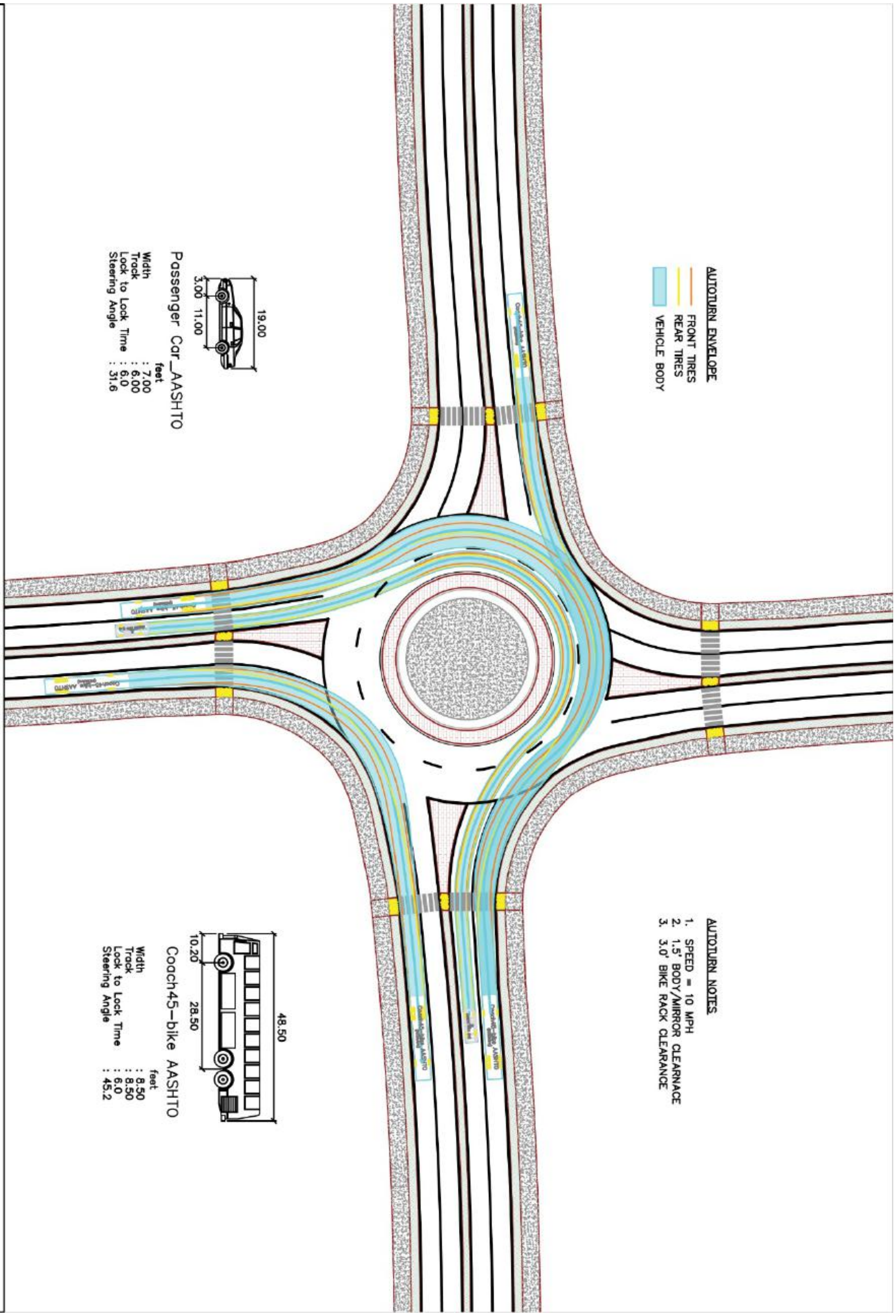


King County METRO

Figure 7:
Double Lane Roundabout AutoTurn Simulation
(KCM Bus60-Bike)

wsp

Date: February 2022

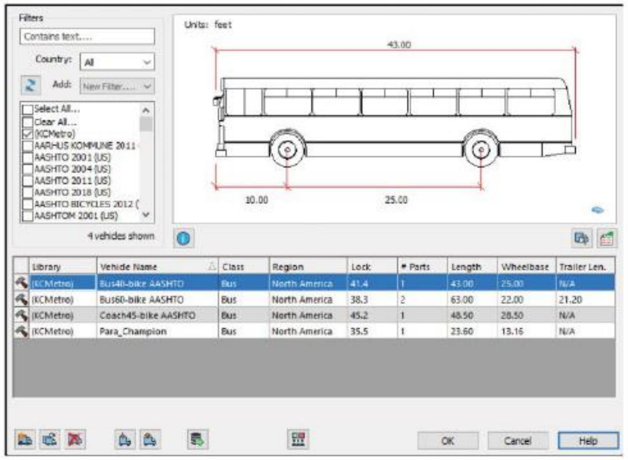


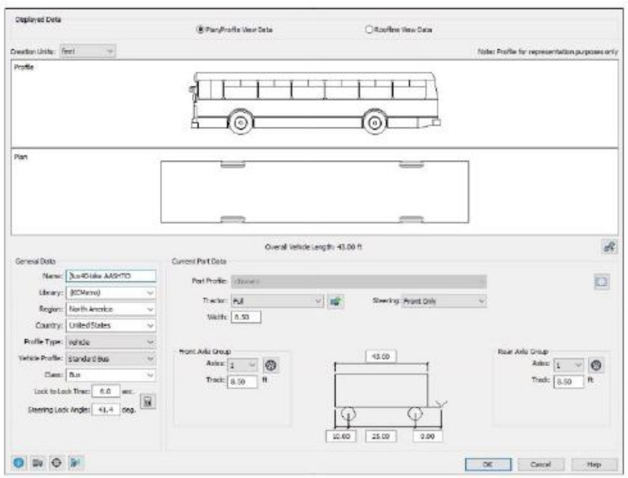
King County METRO

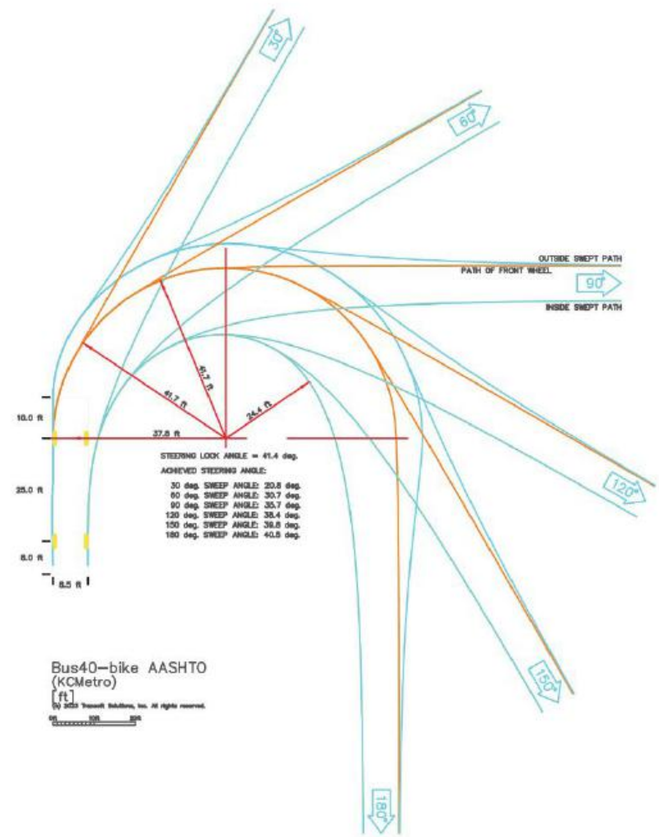
Figure 8:
Double Lane Roundabout AutoTurn Simulation
(KCM Coach45-Bike)

wsp

Date: February 2022





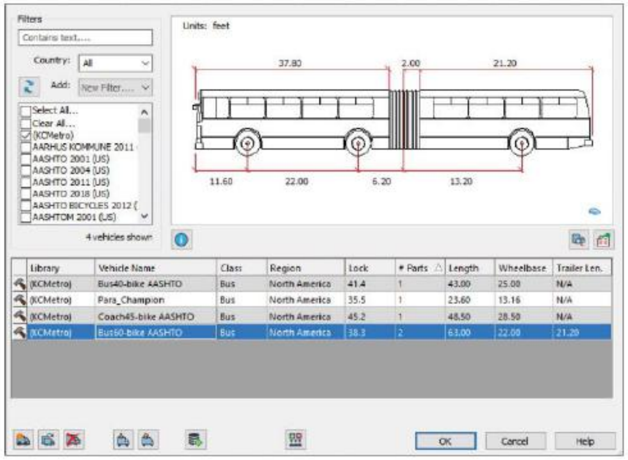


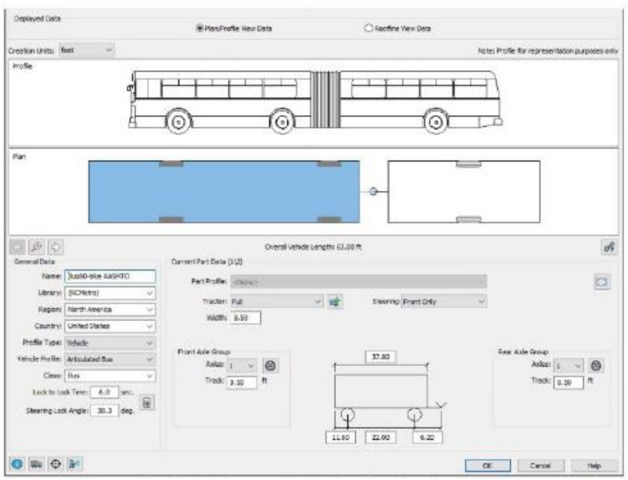
King County METRO

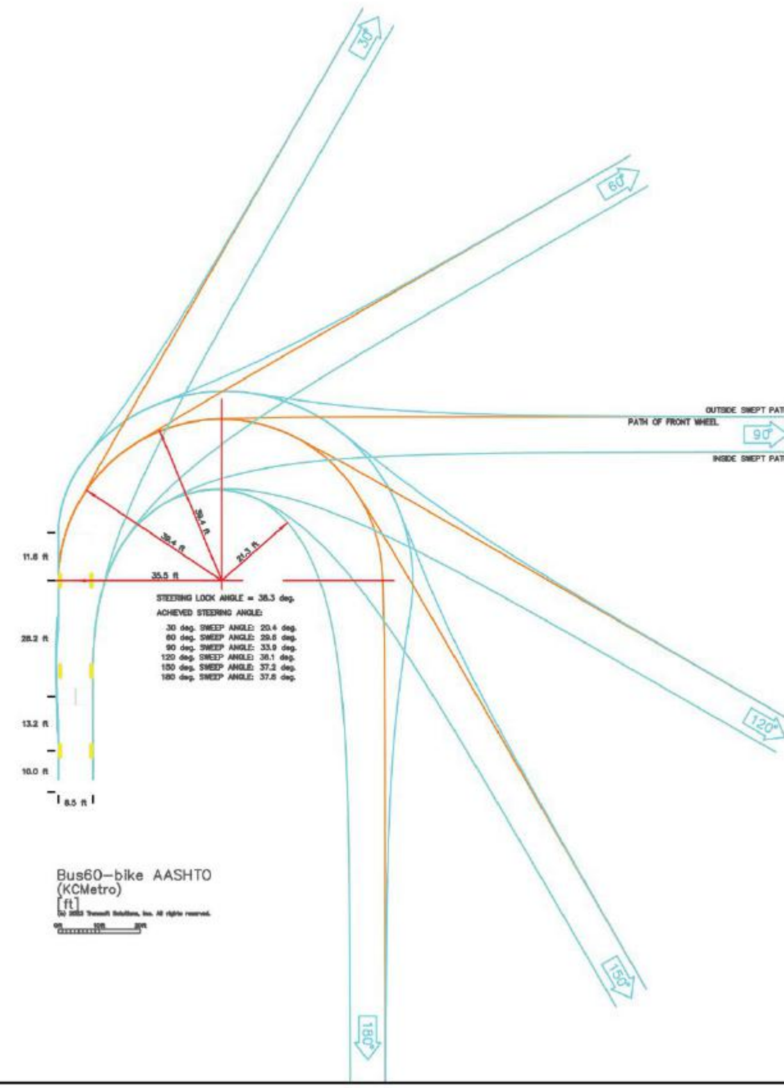
Figure 9:
Bus Parameters
(KCM Bus40-Bike)

wsp

Date: February 2022





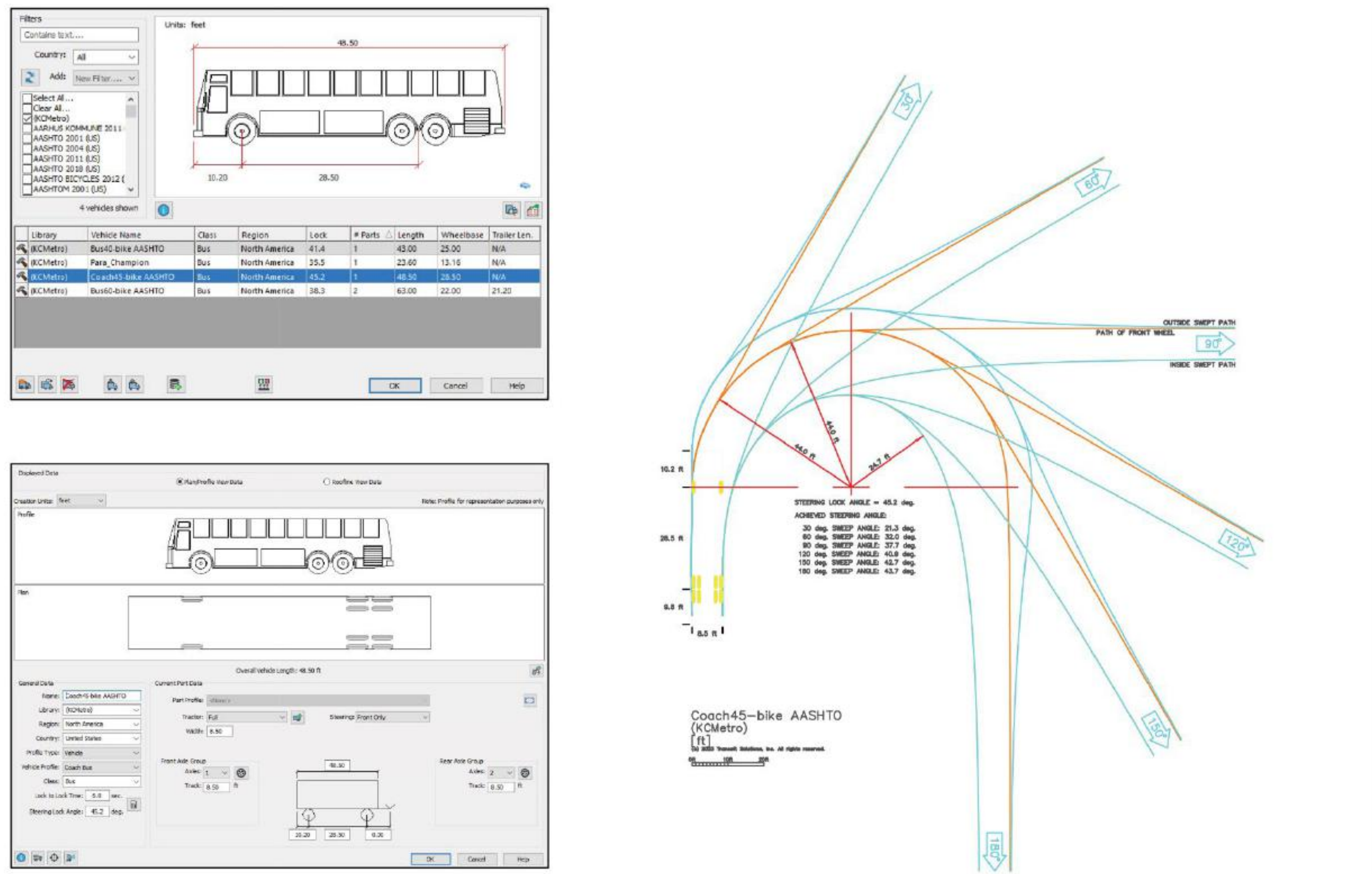


King County METRO

Figure 10:
Bus Parameters
(KCM Bus60-Bike)

wsp

Date: February 2022



Library	Vehicle Name	Class	Region	Lock	# Parts	Length	Wheelbase	Trailer Len.
(KCMetro)	Bus40-bike AASHTO	Bus	North America	41.4	1	43.00	25.00	N/A
(KCMetro)	Para_Champion	Bus	North America	35.5	1	23.60	13.16	N/A
(KCMetro)	Coach45-bike AASHTO	Bus	North America	45.2	1	48.50	28.50	N/A
(KCMetro)	Bus60-bike AASHTO	Bus	North America	38.3	2	63.00	22.00	21.20

King County METRO

Figure 11:
Bus Parameters
(KCM Coach45-Bike)

wsp

Date: February 2022