REPORT 1: RED LANES FUNDAMENTALS

RED LANE FUNDAMENTALS

A Technical Overview Report on Transit Priority Lane Treatments

INTRODUCTION AND SUMMARY OF CONTENTS

PURPOSE OF REPORT

The Capital Area Metropolitan Planning Organization (CAMPO) RED Lanes Study is taking a comprehensive look at transit priority lanes as a potential part of the region's approach to enhancing its transportation system to meet growing demand, improve transit operations, and diversify modal options for local and regional travel. RED lanes are sometimes referred to as business access and transit (BAT) lanes or transit priority lanes. These facilities are an increasingly common component of transportation planning and transit investment across the U.S. and around the world. They can be a cost-effective solution for improving transit operations and service reliability.

This report introduces the key concepts and components of RED lanes, with a focus on typical considerations for planning and implementation. CAMPO defines RED lanes as restricted transit lanes that typically also allow automobile use for:

- Right turns,
- Emergency vehicles, and
- Driveway access.

The primary objective of RED lanes is to optimize bus operations in a corridor. This objective aims to maximize transit competitiveness, reliability, and ridership as well as to expand local and regional travel choices through the dedication of right-of-way. RED lanes also aim to minimize disruption to motor vehicle travel by sharing dedicated lanes with turning vehicles and emergency services. The RED acronym highlights these typical characteristics of RED lanes and reflects the frequent application of red surface treatments to distinguish transit lanes from general use traffic lanes.[1] Although the acronym emphasizes the potential for RED lanes to share space with other motor vehicles, bicycles are also sometimes allowed in transit lanes and a variety of design options are available for implementation that may exclude some or all shared users.

This report is an early step in the development and testing of a RED lanes evaluation process for the CAMPO region, focusing on key concepts and best practices from case studies and literature review.

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[1] Note the application of red surface treatment is not always appropriate and use of the RED acronym does not imply red surface treatment will be used on all or any corridors in the CAMPO region. Appropriate surface treatments should be considered on a case-by-case basis; this report offers details on the costs and benefits of different lane markings.

The goal of this report is to provide a technical overview of RED lanes, explaining clearly what they are and how they function. This includes outlining typical facility design and vehicle operations on facilities that include RED lanes, highlighting best practices for planning for RED lanes, and offering generalized costs associated with different potential components of RED lanes. The findings of this report will inform later phases of the CAMPO RED Lanes Study, including the development of a RED lanes evaluation/prioritization methodology for ranking corridors in the CAMPO region according to their suitability/readiness for RED lane implementation. It is supported by case study reviews of RED lane planning and implementation efforts in 10 peer areas/corridors and a thorough review of relevant industry and academic literature on transit priority lanes and accompanying operational enhancements.

Finally, this report addresses a variety of topics closely related to RED lanes, including bus rapid transit (BRT), TSP, and queue jumps. Each of these topics provide insight into how transit priority lanes and operational enhancements function. However, this report – like the RED Lanes Study overall – makes no attempt to comprehensively address the details of each of these components or their distinctive relevance to CAMPO corridors. That is, the Study does not attempt to prioritize corridors for BRT implementation or intersections for potential queue jumps, etc. Rather, it focuses on the selective prioritization of transit vehicles in RED lanes with the general expectation that other modes may at appropriate times or under appropriate circumstances also utilize those lanes. Lane restrictions may be complemented by operational enhancements as warranted by corridor characteristics and local/regional planning policy.

REPORT STRUCTURE

CONTENTS

This report is structured to facilitate understanding of RED lanes and key considerations at a glance, while providing additional detail from case studies and literature reviews. This is accomplished by including six "cutaway" pages that serve as handouts for overview information. The cutaway handouts explain:

- What is a RED lane?
- Design Features of RED Lanes
- Bus Operations and Service on RED Lanes
- RED Lanes and BRT
- Best Planning Practices for RED Lanes
- Cost Considerations for RED Lanes

These summary pages have been developed based on a review of transit priority lane applications in peer communities as well as academic and industry literature on transit priority lanes and related subjects. They serve as the "Key Findings" from those efforts. Details of each case study and the reviewed publication are found in the later sections of the report.

RED LANES INFORMATION GATHERING CONCEPT MATRIX

To help organize information contained in case studies and the reviewed literature, the RED Lanes Information Gathering Concept Matrix was developed. The matrix simply provides a consistent list of topics, for which findings, recommendations, lessons learned, and general information gleaned from case studies or literature review may be organized and recorded. Use of the matrix allows for quick comparisons across case studies and/or publications on diverse topic areas. The matrix includes the following topic areas:

- Demand

- Operations
- Contexts
- Design
- Other Considerations

Each topic area consists of indicators or sub-topics, for which specific information was sought from each case study and publication reviewed. No single case study or publication addressed all topics in the matrix, but collectively, they provide comprehensive insight into the key considerations, costs, benefits, and design alternatives associated with transit priority lanes. Each major topic area is described briefly below, followed by a blank shell of the Information Gathering Concept Matrix.

Demand

The Demand topic area focuses on travel demand considerations associated with effective implementation of RED lanes. Common demand indicators are transit ridership (within the RED lane corridor) and traffic volumes. In rare cases, multi-modal demand indicators such as mode shares, non-motorized user demand, and person throughput are considered. Each of these indicators provides insight into how a facility is being used. Demand metrics may be derived from observed data or model estimates and forecasts. In some cases, time-of-day considerations – such as demand in peak commuting hours – are important.

Operations

The Operations topic area includes indicators describing the experience of traversing a corridor by the transit or auto mode. For transit, indicators include on-time performance (percent of vehicles arriving at a given stop location on-time, e.g.), travel time reliability (consistency of route travel times, e.g.), service frequency, and average vehicle operating speeds. For the auto mode, vehicle or person delay (generally associated with congestion or inefficient operations) is a common indicator. The operations topic area also includes information on TSP, whether it has been implemented or recommended and under what conditions. As with demand consideration, operational indicators may be derived from existing or modeled data, and time-of-day considerations may be significant.

Contexts

Indicators in the Contexts topic area focus on land uses and activity within/adjacent to a corridor. RED lanes can be a major component of complete streets implementation, a context-sensitive facility design approach that accounts for all users in the right-of-way. Usually, adjacent land uses are a prominent consideration in facility design using complete streets principles. Additionally, consideration of nearby businesses and populations can inform transit service design, such as stop spacing or service frequency. Parking for nearby activities – whether on-street or off-street – may need to be accessed by motorists, thereby influencing RED lane design and/or posted restrictions. Finally, corridor functional and access classes may influence RED lane implementation in a corridor. Generally, contextual information should account for local plans and growth strategies in addition to current conditions.

Design

While the above topic areas are potential major informants of a RED lanes evaluation/prioritization approach, the Design topic area pertains more to the appropriate design options and standards for a RED lane in a given corridor. Design indicators include lane width, number of lanes, and intersection design. Notes on these sub-topics can provide insight into the best approach to implementing RED lanes, when to share lane space with other modes, and when to exclude other modes. Design choices are influenced by travel demand, operational, and contextual cues as well.

Other Considerations

Finally, the Other topic area includes a handful of miscellaneous indicators/sub-topics that are important aspects of RED lane planning and implementation. These include safety considerations and when/how these are directly addressed by transit priority lanes or associated improvements; enforcement considerations to maximize the effectiveness of RED lanes in providing expected benefits; maintenance considerations for RED lanes, focusing especially on red surface treatments; and cost considerations to gauge the expected expense associated with a given RED lane project. Project length is also included for case study summaries.

RED LANES INFORMATION GATHERING CONCEPT MATRIX

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	[Key findings listed by topic and indicator]
	Transit Mode Share	[Gray-shaded cells denote topics not covered in detail]
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	
	Transit Signal Priority	
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	
	Lane Width	
	Intersection Design	
	Separation of Traffic	
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	
	Project length	

WHAT IS A RED LANE?

A RED lane is a transit-priority travel lane with restrictions for other modes. While RED lanes restrict non-transit users within the lane, they do not necessarily exclude them. In fact, buses typically share RED lanes with:

- **R**ight turning cars;
- **E**mergency vehicles; and
- **D**riveway access.

The primary objective of RED lanes is to optimize bus operations in a corridor to maximize transit competitiveness, reliability, and ridership through the dedication of right-of-way. RED lanes also aim to **minimize disruption to drivers** by sharing the dedicated lane space with turning vehicles and emergency services. The RED acronym highlights these typical characteristics of the transit priority lanes and reflects the frequent application of red surface treatments to demarcate transit lanes from general use traffic lanes.[2] Although the acronym emphasizes the potential for RED lanes to share space with other motor vehicles, bicycles are also sometimes allowed in transit lanes and a variety of design options are available for implementation that may exclude some or all shared uses. RED lanes are sometimes referred to as business access and transit (BAT) lanes or simply transit priority lanes.

RED lanes are typically applied in situations where there is a desire or need to **reduce delays associated with congestion**, implement rapid transit improvements along a corridor, or in cases where policy goals seek to **enhance the attractiveness of transit** relative to other modes.

RED lanes can be created through converting an existing traffic lane, eliminating parking, widening a roadway, or utilizing existing unused right-of-way in a median. As noted above, **other non-transit vehicles and users are often allowed in RED lanes**. Non-transit users are typically allowed in RED lanes when transit volumes (ridership and/or service frequencies) are low enough that their presence will not unduly inhibit travel time savings or reliability benefits to transit vehicles or in cases where shared

Bus priority lanes can be implemented in a variety of ways and in a variety of contexts. Other users, like bicycles, taxis, and emergency vehicles can use the lanes. Pavement markings, posted speeds, and parking restrictions vary. (Source: Greater Greater Washington)

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[2] Note the application of red surface treatment is not always appropriate and use of the RED acronym in no way implies that red surface treatment will be applied on all or any corridors in the CAMPO region. Appropriate surface treatments should be considered on a case-by-case basis.

use of the lane will help reduce implementation costs or achieve other policy goals. Emergency vehicles are always permitted to use RED lanes.

There are several different types of RED lanes, including **numerous design alternatives** to suit corridor-specific conditions and policy objectives. They can be located curbside, offset from the curb (adjacent to on-street parking, e.g.), or in a variety of street configurations that meet special situations or needs. The length of a transit lane can vary. In some cases, a RED lane may run along an entire corridor or bus route. However, it may also be desirable to implement a short RED lane, such as a queue bypass, which allows a transit vehicle to bypass a specific bottleneck. RED lanes can also be targeted to specific sections of a corridor, where transit vehicles frequently are delayed by congestion.

An Interior (Offset) Bus Lane retains parking on the curbside and allows motorists making right turns or maneuvering into/out of parking spaces to utilize the lane. In this example, bicycles are also permitted in the RED lane. (Source: A Guidebook on Transit-Supportive Roadway Strategies)

Intersection designs for RED lanes present additional options. RED lanes can continue through intersections or be dissolved at an intersection approach to accommodate the operational and maneuvering needs of transit vehicles and/or other users, while lane placement varies based on routing and facility attributes. Signal phasing and timing at intersections may also need to be modified. **Transit signal priority (TSP) can enhance the effectiveness of RED lanes** by minimizing transit vehicle delays at intersections.

Numerous studies have found that – used in conjunction with traditional signage and lane markings – **red surface treatments are effective at reducing RED lane violations** by restricted users. While it is important to consider that special permission may be needed from regional transportation partners (such as NCDOT and local jurisdictions) before red surface treatments are implemented, numerous successful case studies and recommendations exist from professional organizations, making this application process feasible for most communities. However, **red surface treatments are not necessary for effective RED lane implementation**, and there are cases in which they are not an appropriate component.

RED lanes are most effective in corridors with high-frequency and high-volume transit routes, while the safety of all travelers, traffic volumes and delay in the corridor, density and diversity of adjacent land uses, urban design characteristics, and policy objectives are also important considerations in planning for RED lanes. **RED lanes offer a relatively low-cost solution to enhancing transit service** and can serve as a pre-cursor to bus rapid transit (BRT)

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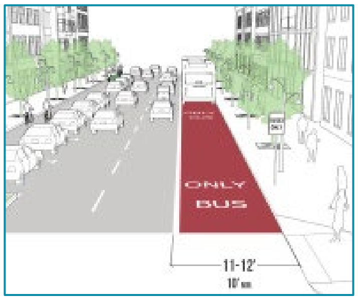
DESIGN FEATURES OF RED LANES

Broadly, RED lanes are transit priority lanes that sometimes allow other users, such as bicyclists or turning vehicles, to share the lane with transit vehicles. Appropriate design of a RED lane varies on a case-by-case basis, depending on transit service, and corridor travel patterns. Several general design options for transit priority lanes are shown below. Designs with bus priority in the median, along the left side of a street, or in a contraflow treatment are inconsistent with the "RED" acronym but may be applicable for other transit priority lanes. They are included to show a range of design options.

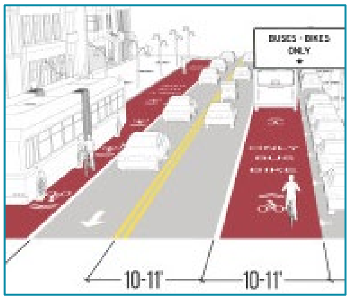
PLACEMENT ON STREET

Curbside Lane



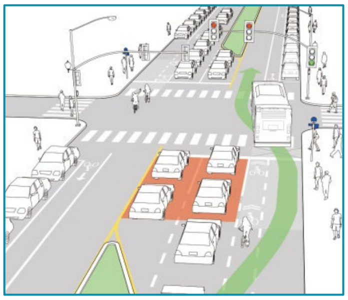
Curbside lanes are located on the outermost lane of a street. Curbside lanes can be created by converting a parking lane or existing travel lane to a part-time or full-time transit priority lane.

Shared Transit/Bicycle Lane



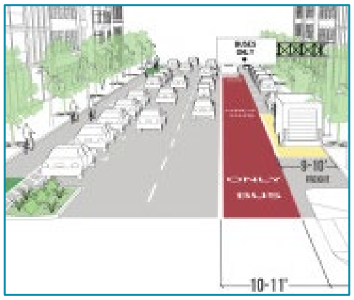
A shared RED lane is typically wider to accommodate shared use with bicyclists and includes bicycle and bus-only markings. These facilities may be used where there is not enough space for separate facilities. for both modes

Queue Bypass



Queue bypasses are short transit lanes intended to allow transit vehicles to bypass congestion and move to the front of a queue. They may be appropriate at bottleneck locations, usually at intersections.

Offset Lane

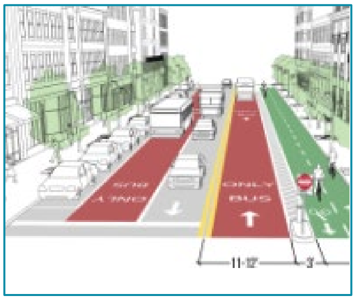


An offset RED lane is separated from the curb by a lane designed for other uses, including on-street parking, deliveries, or right-turning vehicles. Offset lanes are generally only recommended in situations where the conversion to a transit priority lane is possible while still preserving at least two other travel lanes in the same direction.

Two-Way Median Lane

This type of transit facility provides an exclusive running way for transit vehicles. It is often implemented for Bus Rapid Transit (BRT) projects. Other users are not permitted in this configuration. Also, transit-only signaling is typically required, increasing the cost and complexity of installations.

Contraflow Lane



Contraflow lanes allow transit vehicles to travel in the opposite direction on a one-way street. They may be an option when two-way transit service is desired on a one-way street, for short legs to make routing more direct, or where high directionality in traffic may allow buses to take underutilized lane capacity in the non-peak direction.

Left-Side Lane

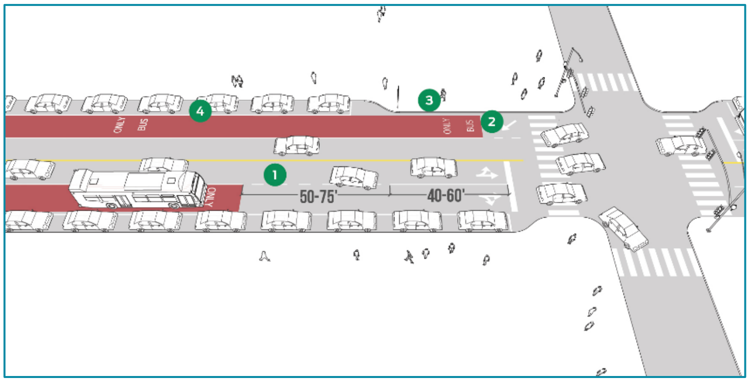
Left-side lanes may be appropriate for express bus routes, areas with large volumes of right-turning vehicles, and when transit routing requires the transit vehicle to make a left turn.

LANE WIDTH AND SEGMENT LENGTH

In most applications, **10-11 ft. is the minimum width necessary for a RED lane**, with 12-13 ft. considered desirable. In situations where a RED lane is shared with bicyclists, 14.5-16 ft. is needed to allow enough space for both modes to safely coexist. These are general best practices described in various sources. Currently, there are no national or NCDOT standards for RED Lanes.

Although **the greatest benefits of RED lanes are realized when they are designated along an entire corridor** or route, benefits can be realized from applications in short segments. There are numerous examples of RED lanes in short targeted segments, based on evaluations that consider feasibility and/or effectiveness (see Washington DC Georgia Avenue case study, e.g.).

Transit lanes can also be dissolved at intersections, where turning movements may limit their feasibility or reduce benefits. In situations where transit lanes dissolve, companion strategies should be considered, such as queue jumps and transit signal priority (TSP).



A transit lane that dissolves at an intersection (Source: NACTO Transit Street Design Guide)

RED SURFACE MATERIAL

Red surface treatments are effective at reducing violations in RED lanes when accompanied by traditional signage and pavement markings. Research has found that red surface treatments can **reduce violations by 50 percent**, and in some cases even eliminate unauthorized use. Special permission may be needed from appropriate agencies to use red treatments to designate RED lanes. Application template letters and case studies are provided in relevant documents reviewed for this report.

It is best practice to utilize a red surface treatment only in situations where RED lane restrictions apply on a full-time basis (i.e., when transit frequencies and ridership are high throughout the day). **Allowing non-transit vehicles to use red-colored lanes during parts of the day reduces their effectiveness.** Some areas have chosen to apply a red color treatment only once, when a transit lane is first designated, with the intent to raise awareness of the new facility. As the red treatment fades, traditional signage and lane markings can be utilized to maintain compliance with restrictions that are in place.

BULB OUTS

Bulb outs, or curb extensions, expand the sidewalk to the edge of the parking lane, reducing delays related to stops by allowing buses to stop in the travel lane. Curb extensions are best suited for areas with high-density development and where on-street parking is present.

A bus bulb out, also known as a curb extension. (Source. NATCO Transit Street Design Guide)

BUS OPERATIONS AND SERVICE ON RED LANES

RED lanes prioritize transit vehicle operations to reduce travel times and improve reliability. Their effectiveness and appropriateness depend in part on the supply and demand of transit service in a corridor. As transit service and performance often varies by time of day, RED lane restrictions can be implemented on a full-time or part-time basis. Additionally, other users are often permitted to share the lane with transit vehicles. Finally, companion strategies like transit signal priority (TSP) can be implemented to improve operations in a corridor.

TYPICAL TRANSIT SERVICE CHARACTERISTICS ON RED LANES

Generally, **transit service should be frequent enough that lane restrictions are effectively self-enforcing.** In cases where bus volumes may not be high enough to accomplish this, lane utilization can be enhanced by allowing other users to share the RED lane, such as bikes, taxies, and right-turning vehicles. While some publications have suggested a minimum of 10 transit vehicles per hour on priority lanes, there is no definitive quantity of service criterion justifying or precluding their implementation.

DURATION OF RESTRICTIONS

RED lanes can be operated on a full-time or part-time basis. **Full-time RED lanes should maintain reasonably frequent service throughout the day.** If this is not feasible or justified by transit demand, part-time RED lanes may still be appropriate. In a part-time scenario, all vehicles may be allowed in the RED lane at off-peak hours. In cases where a RED lane is designated with red surface treatment, lane restrictions should be implemented on a full-time basis, as **allowing all vehicles to use red-treated lanes during parts of the day can reduce their effectiveness**.

SHARED USERS

Transit vehicles may share RED lanes with other users, even when restrictions apply on a full-time basis. Other users that may be permitted include right-turning vehicles, taxis, delivery vehicles, parking vehicles (in an offset-lane, e.g.), bicycles. **The travel time benefits to transit vehicles are greatest when no other users are allowed.** For example, allowing right-turning vehicles in transit lanes reduces the time-savings benefit that transit vehicles receive by half.

A Shared Bus-Bike Lane in Boston, MA (Source: NACTO)

Shared users should be considered in situations where transit volumes and speeds are relatively low or where allowing other users supports broader policy goals. When other users are allowed, RED lane design approaches should account for the shared users and ensure all modes are accommodated safely and comfortably. For example, if bicycles are allowed, wider lanes should be used with conventional bike-lane striping or other markings to clearly delineate space for bicycle and vehicular traffic to allow for safe passing maneuvers. If right-turning vehicles are allowed, strategies such as access management or implementing queue jumps at intersections should be considered to mitigate the impact on transit vehicle speeds.

Emergency vehicles have the right to utilize all available lanes during an emergency, and **RED lanes can provide space for first responders to bypass traffic in general use lanes, especially in congested corridors.**

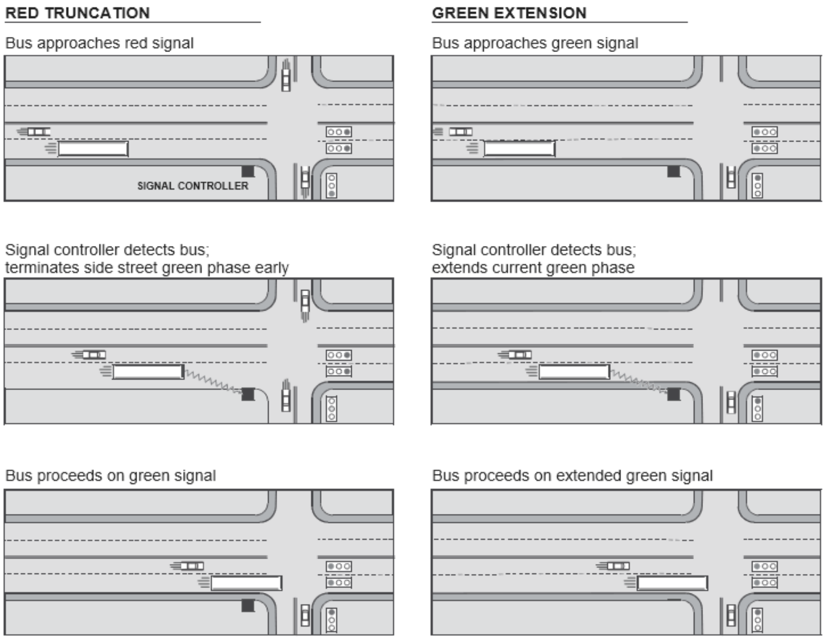
TRANSIT SIGNAL PRIORITIZATION

Transit Signal Prioritization (TSP) is a method for increasing transit vehicle speed and improving reliability through the adjustment of signal timing at intersections. **TSP typically extends a green phase or truncates a red phase if a transit vehicle is attempting to enter an intersection**, thereby decreasing the delay likely to be experienced at a signalized intersection. Unlike signal preemption, TSP does not override a signal. Rather, it changes the length of the green phase at a signal to optimize transit operations.

TSP can be applied in a variety of contexts, such as along an entire corridor that is suitable or at a specific signalized intersection where TSP will benefit operations. It can be deployed in corridors where transit vehicles operate in mixed traffic or as a companion to RED lane or BRT projects. TSP can significantly improve travel time benefits for transit vehicles in dedicated running-way.

TSP is generally most effective in corridors and intersections where transit vehicles experience delays, but where congestion is not so high that the vehicle cannot take advantage of an early or late green cycle. More specifically, general characteristics of intersections suitable for TSP include:

- Peak intersection volume/capacity (v/c) ratio between 0.6 and 1
- High transit ridership (existing or future)
- Approximately four or more buses per hour
- Intersections with far-side bus stop (or the potential to relocate stop to far side) – stops on the near side of the intersection force buses to stop for passenger boarding/alighting before taking advantage of green time.
- Corridors with long signal cycles and/or long distances between signaled intersections



This diagram illustrates the concept of extending green cycles and truncating red cycles that can be applied with transit signal prioritization (TSP) (Source: TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic)

Queue bypasses can help improve the impact of TSP at intersections with higher levels of congestion and v/c ratios above 1. TSP technology adjusts traffic signal timing when a bus is present at an intersection to give priority to the transit vehicle. A queue jump adds to the benefits of TSP by allowing a bus to move ahead of stopped vehicles. The transit vehicle can then reach the intersection and trigger the adjusted signal phase sooner.

RED LANES AND BRT

Bus Rapid Transit (BRT) is defined by the Federal Transit Administration (FTA) [3] as “a high-quality bus-based transit system that delivers fast and efficient service that may include dedicated lanes, busways, traffic signal priority, off-board fare collection, elevated platforms and enhanced stations.” **Transit priority lanes, including RED Lanes, can be integrated into BRT projects where appropriate, or may stand alone as suitable treatments fully independent of BRT considerations.**

BRT projects can be defined as either Fixed-Guideway BRT or Corridor Based BRT. Fixed-Guideway BRT projects must include a dedicated lane for transit vehicles during peak traffic periods for at least 50% of the BRT corridor length. **Both Fixed-Guideway and Corridor Based BRT projects often include a variety of transit priority design treatments** that vary from segment to segment and are customized to the needs and constraints of each segment.

The table below demonstrates the **differences between BRT, Red Lanes, and other transit priority lanes** for several notable design and operations treatments to highlight the differences between these bus priority treatment concepts. Some key differences and commonalities among the three types of bus priority treatments can be summarized as follows:

- The RED Lanes concept, encompassing right turns, emergency vehicles, and driveway access, embodies three elements that are incorporated by definition into the acronym.
- Based on the acronym definition, certain types of design with bus priority in the median, along the left side of a one-way street, or in a contraflow treatment are not applicable for RED Lanes but may be applicable for BRT and for other transit priority lanes.
- In North Carolina (and most jurisdictions nationwide) emergency vehicles are allowed access into bus priority treatment areas by law.
- BRT systems (both Fixed-Guideway and Corridor Based) are defined in large part by service characteristics including service frequency, transit signal priority, and defined stations that including passenger amenities beyond those associated with typical bus stops.
- The majority of treatments are shown in the table as “occasionally”, which means that the element described is not required by definition or law for that treatment, nor is it generally found in the literature to be a typical treatment.

In summary, **project characteristics that would be required for federal funding of BRT projects are not as formally defined in RED Lanes or other transit priority lanes**. However, all three of these bus priority treatment options seek to improve transit service performance in corridors where multimodal demand warrants their consideration. The consideration of appropriate transit priority lane treatments within the CAMPO region therefore benefits from an appreciation of the design elements and lessons learned from case studies across all three treatments.

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[3] https://www.transit.dot.gov/research-innovation/bus-rapid-transit

Transit supportive element	Fixed-Guideway Bus Rapid Transit	Red Lanes	Other transit priority lanes
DESIGN			
Transit lane presence	👍	✓	✓
Right side of roadway	🔍	✓ (By definition)	👍
Median of roadway	👍	✗	🔍
Left side of roadway	🔍	✗	🔍
Contraflow	🔍	✗	🔍
Physically separated from adjacent lanes	👍	✗	🔍
Marked by special pavement color or treatments other than pavement marking	🔍	👍	🔍
Enhanced stations	👍	🔍	🔍
OPERATIONS			
Transit lane shared by			
Right turn vehicles	🔍	✓ (By definition)	🔍
Emergency vehicles	✓ (By law)	✓ (By law)	✓ (By law)
Driveway access	🔍	✓ (By definition)	🔍
Private shuttles/taxis	🔍	🔍	🔍
Bicycles	🔍	🔍	🔍
Frequent bi-directional peak period and weekend services	✓	👍	👍
Transit signal priority	👍	🔍	🔍
Off-board fare collection	👍	🔍	🔍
Route/vehicle "branding"	👍	🔍	🔍

✓	👍	🔍	✗
Yes	Typically	Occasionally	No

BEST PLANNING PRACTICES FOR RED LANES

RED lanes and related projects can be complex. The following best practices help ensure project success.

BUILDING PARTNERSHIPS AND ENGAGEMENT

Transit-supportive treatments, including RED Lanes, can be complex projects that require coordination between multiple entities. In many cases, roadway and transit agencies, local and state governments, enforcement entities, and stakeholders may be involved at various steps in a project. In some situations, state or local laws may need to be changed. Therefore, **it is important to develop partnerships among agencies and conduct public engagement early and often**. In some cases, agencies and institutions may have competing goals, so it is important to identify this early and address potential differences. One strategy to build partnerships is to focus on developing open lines of communication. Doing so allows information to be shared, such as data and analysis, which can help overcome obstacles and build momentum.

HAVE A CLEAR POLICY FRAMEWORK

Transit-supportive treatments are made within a specific local policy environment. A policy framework establishes local planning goals and informs project priorities and appropriate implementation approaches. While transit-supportive facilities are easier to implement within policy frameworks that encourage multi-modal transportation, a variety of strategies can help projects move forward in less supportive policy environments. *TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies*[4] identifies four example policy scenarios and suggests different approaches for working within them. The table below, adapted from the guidebook, can be helpful in identifying a local policy scenario and calibrating an approach.

Scenario	Scenario Description	Transit-Supportive Strategies/Approaches	Evaluation Metrics Typical in Scenario
Maintain Existing Motorized Vehicle Operations	Transportation policies focus on maintain existing motor vehicle operations. Little flexibility permitted for transit-supportive strategies.	Prioritize strategies that require low levels of coordination with highway agency.	N/A
Maintain or Improve (Reduce) Person Delay	Transportation policies focus on reducing per person delay and will consider negative impact on auto if there is net reduction in per person delay.	Pursue approaches that reduce person delays and have minimal impact on auto operations in addition to operations strategies that require limited coordination.	Person Delay by Mode Net Reduction in Person Delay
Maintain Operations at or Above Standard	Transportation policies seek to maintain Level of Service (LOS) and volume-to-capacity ratio (v/c). Degraded auto conditions allowed if minimum thresholds are met.	Many transit-supportive strategies could work. Emphasize strategies that focus on less congested roadway segments.	Level of Service (LOS) Volume-to-Capacity ratio (v/c)
Favor Transit Service	Transportation policies factor transit service above other modes, especially on designated corridors	Transit-supportive strategies are easiest to implement in this environment.	Safety, capacity, access, parking, transit frequency, and cost/benefit

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[4] *TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies*. Transportation Research Board (TRB), 2016. https://www.nap.edu/download/21929

FOCUS ON KEY METRICS AND A SIMPLE ANALYSIS APPROACH

Given an understanding of a specific policy environment, **a narrow set of key factors may be defined to inform decision-making and reflect policy goals**. In the transit priority treatments literature, there is a set of common considerations when analyzing priority lanes and related improvements. While this list is not comprehensive, it provides a sound foundation for RED lanes planning analyses.

- Transit vehicle volume
- Person throughput (by all modes)
- Automobile level of service (LOS)/delay
- Volume-to-capacity ratio (v/c)
- Reliability/travel time variability
- Safety concerns
- Available right-of-way (ROW)
- Physical/spatial considerations (parking, access, right turns)

It may not be feasible to evaluate all projects or corridors based on every measure chosen. **A tiered approach can make a larger analysis more feasible by filtering out potential candidate corridors in phases**. For example, a 2015 analysis in Baltimore used a tiered approach to filter candidate corridors. The table below, adapted from a publication reviewing the analysis, identifies metrics used in each phase.[5]

Analysis Phase	Performance Measures Used
Candidate Street Identification	Transit Frequency, transit ridership, travel time delay, reliability
Preliminary Criteria	Level of bus service planned, person throughput by mode
Detailed Screening	Person throughput, person delay, volume (pear hour, peak direction), passengers per hour, travel time, average speed, level of service (LOS), volume-to-capacity (v/c), population near corridor, transit-dependent population near corridor, connectivity/transfers, emergency route, freight route, lane width, right turns at intersections
Full Analysis	Traffic operations analysis, including Synchro models, evaluating delay on automobile traffic, identifying impact on LOS and v/c metrics

IMPLEMENTATION AND OPERATIONS

Agency coordination in RED lane implementation can be facilitated through a memorandum of understanding (MOU). An MOU can discuss roles and responsibilities relating to planning, design, construction, maintenance, and enforcement of new transit-supportive facilities. Specific guidance for developing interagency agreements can be found in *TCRP Legal Research Digest 42: Transit Agency Intergovernmental Agreements: Common Issues and Solutions (Thomas 2012).*

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[5] *Developing Dedicated Bus Lane Screening Criteria in Baltimore, Maryland.* Transportation Research Record, 2018. https://journals.sagepub.com/doi/abs/10.1177/0361198118797827

COST CONSIDERATIONS FOR RED LANES

Capital and operations costs for many transit-supportive facilities will depend on design considerations and local conditions. The most accurate estimates for project budgeting should be made through obtaining capital, operations, and maintenance unit costs from local governments and state DOTs. This section provides general guidelines for high-level cost estimates for RED lanes and supporting treatments based on a review of prior projects and literature.

CAPITAL COSTS

Capital costs for a RED lane can vary widely based on local and regional contexts and the nature of transit-supportive treatments being considered. The table below highlights planning-level cost estimates identified in the literature for the capital cost of various transit priority improvements.

Transit Lane Treatment	Capital Cost
Transit Priority Lane	
Conversion of existing lane (re-striping and signage)	$50,000 to $100,000 per mile (2010 dollars, TCRP 83[6]) $200,000 per mile (2015 dollars, Miami study[7])
Curb or off-set lanes	$2 to $3 million/lane-mile (2007 dollars, TCRP 83)
Median transitway (bus)	$5 to $10 million/lane-mile (2007 dollars, TCRP 83)
Standard Surface Paint	$7.50 per Sq. Yd. (2015 dollars, GRTC Report[8])
High Friction Epoxy Coating	$28.50 per Sq. Yd (2015 dollars, GRTC Report)
Pigmented / Color Aggregate Asphalt (Red)	$42.30 per Sq. Yd (2015 dollars, GRTC Report)
Transit Signal Priority	
Transit Signal Priority (TSP) - upgrade existing hardware	$5,000 or less per intersection (2010 dollars, TCRP 83)
Transit Signal Priority (TSP) - new hardware	$20,000-$30,000 per intersection (2010 dollars, TCRP 83)
Enforcement	
Enforcement – Automated Camera	$130,000-143,000 (2017 dollars) per enforcement camera (MWCOG)[9]
Other Supporting Treatments	
Curb Extension	$40,000 to $80,000 each in San Francisco (2010 dollars, TCRP 83)
Queue Jump (utilizing existing roadway)	Signing and striping costs: $500 to $2,000 (2010 dollars, TCRP 83). Video or loop detection: $5,000 to $15,000 (2010 dollars, TCRP 83) *Note: If new lane is required, costs will vary widely.*

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[6] *TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic*. Transportation Research Board (TRB), 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

[7] *Bus Lanes in Downtown Miami: Final Report*. Miami Dade TPO, 2015. http://miamidadetpo.org/library/studies/downtown-miami-bus-lanes-final-report-2015-12.pdf

[8] *GRTC Bus Rapid Transit Project Geotechnical and Pavement Modifications Report,* RK&K/KimleyHorn. 2015. http://ridegrtc.com/media/annual_reports/GRTC_BRT_Geotech_Pavement_Mod_Report_Version_3.0.pdf

[9] Bus Lane Enforcement Study. Metropolitan Washington Council of Governments (MWCOG), 2017. https://www.mwcog.org/assets/1/28/10062017_-_Item_12_-_DO_NOT_PRINT_-_Bus_Lane_Enforcement_Study_Final_Report.pdf

OPERATING AND MAINTENANCE COSTS

In additional to capital expenses, **transit-supportive treatments often add operational and maintenance costs**. At the same time, it is important to consider that there can also be savings associated with transit-supportive features, specifically relating to transit vehicle travel times and reliability, which in turn may reduce costs. The table below identifies general guidance and estimates identified in literature for operational and maintenance costs.

Treatment	Operations and Maintenance (O&M) Cost Considerations
Transit Priority Lane	
Transit lane (conversion from existing lane)	**Negligible incremental operating and maintenance costs**; more frequent maintenance probably due to greater wear and tear associated with bus operation. [10]
Transit lane (new lane)	O&M costs typically **under $10,000 per lane-mile per year** (based on national average O&M costs for arterial streets). Most transit agencies have fully allocated or marginal O&M cost models that have vehicle hours and peak vehicle requirements as primary input. Analysis of revenue service travel speeds and times is necessary to determine the degree to which these would decrease as the result of the bus lanes. [11]
Red surface treatment	• Depending on the material used, red surface treatments need to be re-applied after their expected life cycle. In general, **red paint lasts approximately 3-5 years**. More expensive materials can last longer.[12] • A 2017 benefit-cost analysis prepared by MWCOG estimated red lane surface treatment maintenance costs at **$10,000 per mile**. (2017 dollars, MWCOG) [13] • Red treatments generally improve bus travel times and reduce delays, resulting in time savings. However, little data exists on quantifying savings.[14]
Transit Signal Priority	
Transit Signal Priority (TSP)	Maintenance costs vary based on the implementation, including whether existing or new hardware is required. **Roadway agency and transit agency maintenance costs are likely to increase**. Additionally, staff training will likely be needed. [15]
Enforcement	
Enforcement – Police	**$49.50 per hour** (2017 dollars, MWCOG) [16]
Enforcement - Cameras	Costs vary depending on circumstances, but can be expected in the range between **$15 for bus-mounted cameras to $415 per week for stationary cameras** (2017 dollars, MWCOG)

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[10] *TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic*. Transportation Research Board (TRB), 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

[11] ibid

[12] Primer on Transit Lane Conspicuity Through Surface Treatment. Transportation Association of Canada, 2010. https://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/primer-transit-conspicuity2010.pdf

[13] Bus Lane Enforcement Study. Metropolitan Washington Council of Governments (MWCOG), 2017. https://www.mwcog.org/assets/1/28/10062017_-_Item_12_-_DO_NOT_PRINT_-_Bus_Lane_Enforcement_Study_Final_Report.pdf

[14] TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies, 2016. https://www.nap.edu/download/21929

[15] Bus Lane Enforcement Study. Metropolitan Washington Council of Governments (MWCOG), 2017. https://www.mwcog.org/assets/1/28/10062017_-_Item_12_-_DO_NOT_PRINT_-_Bus_Lane_Enforcement_Study_Final_Report.pdf

[16] ibid

CASE STUDIES

RED lanes and similar transit priority treatments are increasingly seen in cities across the U.S. and around the world. They are broadly seen as a cost-effective solution to making transit travel times competitive with auto travel times, enhancing on-time performance and travel time reliability for transit vehicles and riders, and implementing complete streets solutions that enhance safety, comfort, and efficiency for all users of a facility.

This section summarizes 10 case study examples of transit priority lanes in peer regions in the U.S. The case studies provide real-world examples of how transit priority treatments have been implemented in other areas, how they have performed, and how they have been received by the traveling public. Collectively, they contribute to an understanding of best practices for RED lanes planning and implementation, offering lessons learned from direct experience.

The selection of case study projects and communities was informed by several factors. First, projects were selected from "peer" areas. This means that the contexts in which a transit priority treatment was implemented are similar to the contexts in which they are most likely to be deployed across the CAMPO region. At a corridor level, density and diversity of development in the project vicinity was considered; at the regional level, regions with auto-oriented development patterns, high growth rates, and regional population figures similar to CAMPO were generally considered. In some cases, regions with notably larger or smaller populations were included to demonstrate the potential for RED lanes in areas of varying size and urbanization levels. Generally, the case studies show RED lanes can be an appropriate and effective regional mobility strategy in regions of all sizes.

Additionally, the case studies include examples of transit priority lanes as well as bus rapid transit (BRT). The inclusion of BRT projects is helpful because they often incorporate transit priority treatments like exclusive or restricted bus lanes to enhance travel times and ensure reliability of service. RED lanes can offer similar benefits. Moreover, BRT has been identified as an important transit technology option for increasing multimodal travel choices in the CAMPO region, and RED lanes may serve as a component of BRT implementation or a stepping stone toward BRT implementation in certain corridors. Finally, in many cases, the transit priority treatments implemented for BRT bring advantages to other fixed route services that utilize (portions of) the same corridors. Thus, BRT treatments – especially priority transit lanes and transit signal priority (TSP) – can provide benefits to multiple routes.

A brief outline of the case studies included in this section is provided below, followed by the details of each case study under its respective heading. Three case studies were selected for detailed review based on the similarity of issues and/or analysis needs relative to the RED Lanes Study, and these are addressed first. The remaining seven case studies are shorter and follow in alphabetical order.

1. **Richmond (Pulse BRT)** – This project includes corridor treatments supporting implementation of a BRT line, with design variations highlighting alternative approaches to implementation and including TSP and queue jumps at select locations. The Richmond region is similar in size to the CAMPO region with similar transportation infrastructure and transportation policy history.
2. **Orlando (LYMMO)** – This collection of bus priority lanes in Downtown Orlando facilitates connections among transit, work and entertainment destinations, and parking facilities throughout the area. Dedicated bus lanes preserve bus reliability in a congested area. LYMMO offers a potential model for

addressing transit connectivity needs in Downtown Raleigh and other urban centers in the CAMPO region.

3. **Baltimore (dedicated bus lanes)**– As part of a regional system overhaul, Maryland MTA created dedicated bus lanes on multiple urban corridors. The majority of the dedicated bus lanes are shared with bicycles, and in cases where they run adjacent to on-street parking, motorists can use the lane while maneuvering into or out of a parking space. There is currently one localized case where the bus lane restrictions are only in force for select hours of the day, and turning vehicles are also allowed to use the lane. Emergency vehicles are always permitted to utilize the bus lanes as needed. The case study provides examples of alternative designs relative to parking and time-of-day restrictions.
4. **Albuquerque (ART)** – Example of BRT implementation in a smaller region with typical activity densities in transit-supportive corridors similar to the CAMPO region. Service near a sizeable university (UNM). Delayed start to service due to limited range of purchased electric vehicles.
5. **Cleveland (Health Line BRT)** – Well-studied BRT implementation, demonstrating median-running transit lanes with strong ridership and development stimulation. The line has faced TSP and fare enforcement challenges that suppress travel time benefits.
6. **Eugene (EmX)** – Example of BRT implementation in smaller region with similar typical activity densities in transit-supportive corridors similar to the CAMPO region. Portions of dedicated lanes include landscaping and a central grass strip straddled by buses, demarcating the bus-only space. On some one-way streets, the bus lane is in a center exclusive lane, allowing right-turning vehicles to utilize the curbside lane.
7. **Jacksonville (Southeast Corridor)** – Example of short segments (small percentages of route alignments) utilizing bus priority lanes to enhance speed and reliability of transit service. Restrictions are only applicable during peak commuting periods.
8. **Los Angeles (Wilshire Blvd Transit Lanes)** – Example of transit priority lanes in a very large metropolitan area with high density development nearby. Bus-only restrictions are in place during peak hours and right-turning vehicles are permitted to use the lanes. Enforcement has been a challenge, with many motorists using the lanes for through movements at intersections. The lanes may be a pre-cursor to BRT along Wilshire Blvd.
9. **Omaha (ORBT)** – Example of emphasis on a single primary corridor, utilizing transit priority lanes in dense urban areas and TSP in low/moderate density suburban areas. Includes a potential contra-flow transit lane on a one-way street to streamline routing for patrons.
10. **Washington DC (Georgia Avenue)** – Example of short segments (small percentages of route alignment) utilizing bus priority lanes to enhance speed and reliability of transit service in a heavily-congested corridor within a large metropolitan area. Project is a pilot that may be extended based on performance and policy initiatives in the Georgia Avenue corridor.

RICHMOND


A Pulse bus picks up passengers at an elevated station, which allows more accessible at-level boarding. (Source: Greater Greater Washington.)

The GRTC Pulse opened in June 2018, with a 7.6-mile route with buses traveling in dedicated curbside lanes, an exclusive median busway, and general-use lanes. The route, which has an estimated travel time of 37 minutes, runs east and west through Richmond and serves an estimated 33,000 residents and 77,000 jobs within a half-mile of its path.[17,18]

The dedicated bus lanes run through downtown Richmond, providing stops at local universities (Virginia Commonwealth University - Monroe Campus and Virginia Union University) and a reinvigorated district with art, restaurants, and retail shops. The route is sponsored by two of the area's largest health systems, Bon Secours Richmond Health System and Virginia Common Wealth University Health System.[19] Since opening, the $64.9 million project has exceeded ridership projections, drawing an average 6,000 passengers daily.

BACKGROUND

The Pulse's east-west route through Richmond connects 14 stations. The technology along the route and on the specially-branded vehicles give buses priority at intersections (through transit signal prioritization) and the ability to move ahead of queuing vehicles (through queue jumps) at select intersections. These operational treatments make the run-time along the route faster and more reliable. All stations have a uniform design and feature real-time arrival information, a route-wide map spanning the back of the station, and traditional wayfinding signage. [20,21,22]

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[17] *GRTC Pulse Project Fact Sheet*. Greater Richmond Transit Company. Accessed Jan. 24. http://www.ridegrtc.com/media/main/14694.3_LANE_GRTC_FactSheet_Single_AltBlue.pdf

[18] *Prepare for the Pulse: Richmond's bus rapid transit system launches June 24*. Richmond Times-Dispatch. Accessed Jan. 24. https://www.richmond.com/news/local/city-of-richmond/prepare-for-the-pulse-richmond-s-bus-rapid-transit-system/article_b6d76b44-b8ba-5f9b-bd01-344f3127be22.html

[19] *GRTC Pulse*. Greater Richmond Transit Company. Accessed Jan. 24. http://ridegrtc.com/brt

[20] *GRTC Pulse Project Fact Sheet*. Greater Richmond Transit Company.

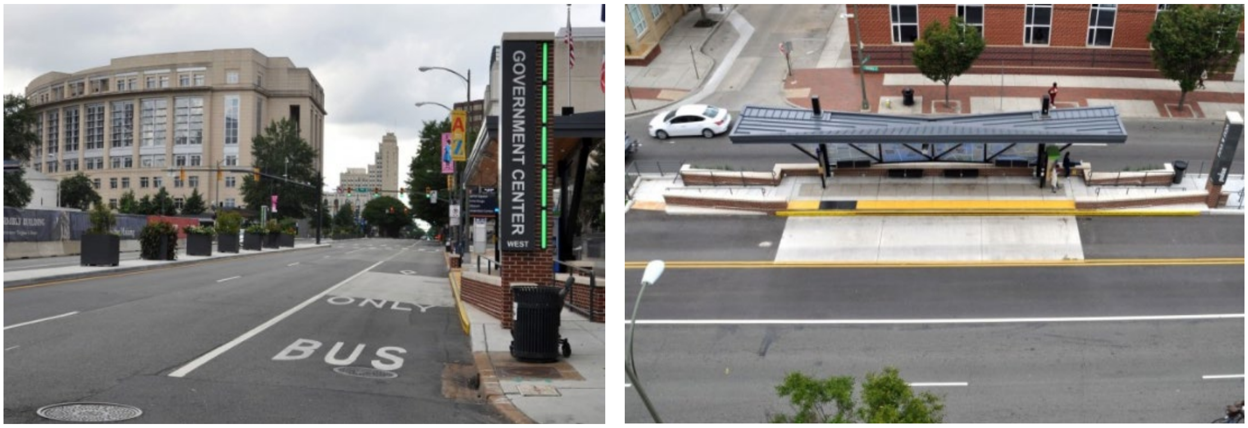
[21] *Prepare for the Pulse: Richmond's bus rapid transit system launches June 24*. Richmond Times-Dispatch.

[22] *Take a photo tour of Richmond's new Bus Rapid Transit*. Greater Greater Washington. Accessed Jan. 24. https://ggwash.org/view/69056/xx-photos-of-richmonds-new-brt

All stations are elevated to allow for level boarding (riders can board and alight the vehicle without steps or ramps), increasing accessibility for passengers and decreasing vehicle dwell time. Riders can prepay their fares with a mobile app or use machines at the stations that allow riders to pay with cash, credit, or tap cards distributed by the operator, a system that helps decrease dwell times due to fare collection.[23]

Approximately 3.2 miles of the route has dedicated bus lanes. The bus-only lanes have been implemented as curb-running lanes and a median busway in different sections of the route. Near the east and west ends of the route, vehicles operate in general use lanes with mixed traffic. The curbside bus-only lanes are reserved for buses at all times, seven days a week. Bikes are permitted in these bus lanes at all times as are cars making right turns as they approach the intersection. The median-running bus lanes are strictly bus-only. Bikes and turning vehicles are not permitted. To make left turns in areas with median-running lanes, motorists have their own left turn lanes and green arrow phase. Pulse buses must wait for these left turns to finish before they can proceed along the busway.

Starting at the easternmost station at the Rocketts Landing riverfront development, buses run in mixed traffic for two miles before reaching the Main Street station. Dedicated lanes begin in downtown as the route turns onto Broad Street, where the vehicles have exclusive use of the curbside lane. This area connects nine stations that provide access to the Convention Center, Government Center, and VCU Medical Center.[24] When the route reaches Foushee Street, the dedicated lanes shift lanes to the median, forming an exclusive busway for 2.5 miles, ending at Thompson Street.[25] West of Thompson Street, the buses return to mixed traffic until they reach the western terminus at the Willow Lawn Shopping Center.



The dedicated right-of-way used by The Pulse is located along the curb (left) or in a median busway (right). (Source: Greater Greater Washington)

In the median busway portions, eastbound and westbound stations are separated so that each is found on the "far side" of an intersection. This minimizes the space taken in the median for the stations and follows best practices for stop location to maximize the benefits of transit signal priority. Riders can enter and exit stations in the median busway via intersection crosswalks that connect to station ramps. The median-

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[23] *Take a photo tour of Richmond's new Bus Rapid Transit*. Greater Greater Washington.

[24] *Frequently Asked Questions.* Greater Richmond Transit Company. Accessed Jan. 24. http://ridegrtc.com/brt/frequently-asked-questions/

[25] Ibid

running busway minimizes conflicts with vehicles entering the road from side streets and entrances,[26] but it precludes opportunities for sharing the bus lanes with other modes, such as bicycles and turning vehicles.

The Pulse operates from 5:30 a.m. to 11:30 p.m. on weekdays and 6 a.m. to 11:30 p.m. on weekends. Buses run every 10 minutes from 7 to 9 a.m. and 4 to 6 p.m. and 15 minutes at other times. Fare costs area $1.50, (the same as for other local bus routes) and 75 cents for reduced-fare customers.

Bon Secours Richmond Health System and VCU Health System have agreed to pay $425,000 per year for five years for Pulse operating costs.[27] VCU is on the bus line in downtown and St. Mary's Hospital, which is owned by Bon Secours, is about a mile from the western end of the line.[28] The cost of constructing the system was $64.9 million, which included $7.6 million from the City of Richmond.[29]

RIDERSHIP AND REACTION

Construction began in August 2016 after several years of planning. Studies in the early 2000s pointed to the need for rapid transit, with a Broad Street Rapid Transit Study dating to 2009.[30] Supporters considered approving the plan the first step toward creating a regional transit system. Opponents of the project argued that, among other concerns, the service did not extend to communities that were not served by transit at the time.[31]

Ridership has outpaced expectations. The service had a projected average daily ridership of 3,500, but that figure had reached 6,000 daily as of September 2018. Sunday ridership was projected to be about 1,600 but has reached 2,000 to 3,000. In its first week, during which GRTC offered free fares, it drew 56,952 riders. Last summer, the bus operator reported that ridership had steadily increased with revenue-generating service to about 30,000 to 36,000 per week.[32] Ridership has been aided through partnerships with Virginia Commonwealth University and Richmond Public Schools that allow students and faculty to ride free.[33]

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[26] *Frequently Asked Questions*. Greater Richmond Transit Company.

[27] *Prepare for the Pulse: Richmond's bus rapid transit system launches June 24*. Richmond Times-Dispatch.

[28] *GRTC announces $6.4 million sponsorship of Pulse bus line by VCU Health, Bon Secours*. Richmond Times-Dispatch. Accessed Jan. 24. https://www.richmond.com/news/local/city-of-richmond/grtc-announces-million-sponsorship-of-pulse-bus-line-by-vcu/article_e300b40e-d37b-5741-b4b0-1796e085336b.html

[29] *Frequently Asked Questions*. Greater Richmond Transit Company.

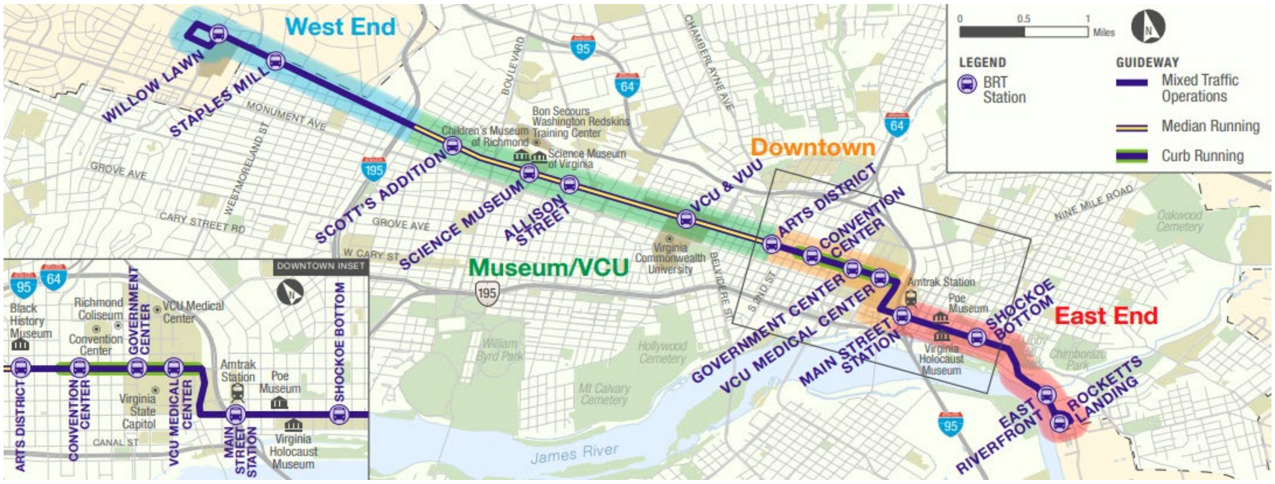
[30] *Broad Street Rapid Transit Study Project Overview and History*. Greater Richmond Transit Company. Accessed Jan. 24 http://ridegrtc.com/media/main/brt/Broad%20Street%20Rapid%20Transit%20Study%20Overview%20and%20History.pdf

[31] *After heated debate, Council approves $49 million bus rapid transit project*. Richmond Times-Dispatch. Accessed Jan. 24. https://www.richmond.com/news/local/city-of-richmond/after-heated-debate-council-approves-million-bus-rapid-transit-project/article_7833e688-670d-5c5c-b6d1-a63818d0ff9d.html

[32] *GRTC Pulse Ridership Continues to Exceed Expectations Three Months In*. Greater Richmond Transit Company. Accessed Jan. 24. http://ridegrtc.com/news-initiatives/press-releases/grtc-pulse-ridership-continues-to-exceed-expectations-three-months-in/

[33] *Despite outperforming ridership goals, GRTC is $1 million below budgeted revenue*. Richmond Times-Dispatch. Accessed Jan. 24. https://www.richmond.com/news/local/city-of-richmond/despite-outperforming-ridership-goals-grtc-is-million-below-budgeted-revenue/article_16a49998-2dd3-5f1d-b3a4-7ae451e7a34a.html

Despite the high ridership, service is nearly $1 million below budgeted revenue, with some pointing to lax fare enforcement as a problem.[34]



GRTC Pulse route and stations. (Source: Greater Richmond Transit Company)

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[34] *Despite outperforming ridership goals, GRTC is $1 million below budgeted revenue*. Richmond Times-Dispatch.

RICHMOND PULSE CASE STUDY

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	11,900 (2015) to increase to 14,400 in 2035
	Transit Mode Share	
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	10 to 15 minutes mornings; 30 minutes late evening and early mornings
	Transit Signal Priority	Yes
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	On-street parking along Broad Street is underutilized with occupancies between 30% and 60% for all time periods studied. 306 parking spaces reduced due to BRT
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	3 lanes in each direction
	Lane Width	10' x 2 directions median running Bus priority lanes. (West of Downtown) 10' x 2 directions curb running Bus priority lanes. (downtown) Mixed traffic (east of Downtown)
	Intersection Design	Separate signals for Buses.
	Separation of traffic	Before - 6 lanes mixed traffic After - 4 lanes mixed traffic + 2 bus lanes (without red paint), bikes allowed in transit lanes
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	$49.8 million ($24.9 million TIGER grant)+($16.9 million – Virginia DRPT)+($7.6 million – City of Richmond)+($400,000 – Henrico County)
	Project Length	7.6 miles with 14 stops

ORLANDO

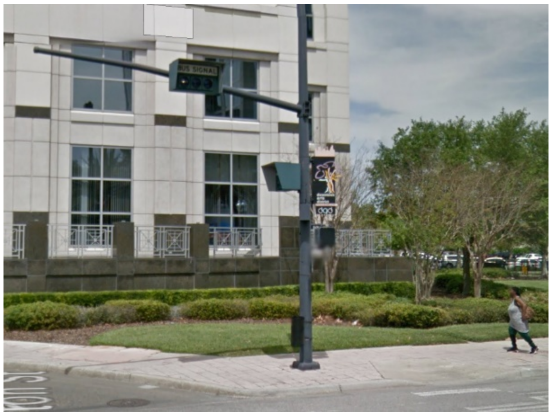
LYMMO opened in 1997 in downtown Orlando as a branded downtown circulator route supported by transit priority lanes. It is considered one of the nation's first bus-rapid transit systems.[35] When introduced, it was the latest in a succession of circulators that provided transit from parking garages on the periphery of downtown to work and entertainment destinations in the central business district. The service has remained free since opening with funding provided by Orlando's Downtown Development Board and Parking Division.[36]

BACKGROUND

LYMMO began with a single three-mile loop, now called the Orange Line, connecting the Centroplex Garage to Orlando City Hall. Today, LYMMO has since expanded to include four downtown lines, with the additional routes utilizing the dedicated right-of-way for part of the trip and running in mixed traffic elsewhere. The bus frequencies range from a minimum of five minutes during business hours and 20 minutes at other times.[37] Two routes, the Orange and Grapefruit lines, provide connections to SunRail, Central Florida's commuter rail system.

LYNX describes the LYMMO service as "rail like," pointing to the dedicated bus-only lanes.[38] Magnolia Avenue, which the north-south dedicated lanes run along, received special design focus during the creation of the service, with the aim of integrating streetscaping, landscaping, and bus facilities.

The two-way dedicated lanes are delineated from traffic with solid, white lines and raised reflectors for most of the route. A raised median separates the north and south bus lanes on Magnolia Avenue, a space filled with at-grade landscaping, planter columns, and custom-designed light poles. The medians widen at stations to accommodate covered bus shelters for northbound passengers. A special paint scheme, paving, and hardscape helps to further distinguish the dedicated bus lanes from adjacent general-use lanes.[39]



A bus-only signal shown above controls LYMMO vehicles in downtown Orlando. (Source: Google Street View)

Intelligent Transportation System elements along the route include a sensor embedded in the street that tracks vehicle locations, allowing buses to preempt traffic signals and receive crossing priority (a form of transit signal priority). The technology also updates the location of buses on kiosk maps and triggers audio and blinking pavement lights to alert riders to the

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[35] *LYMMO History/Timeline*. LYNX. Accessed Jan. 21. https://www.golynx.com/plan-trip/riding-lynx/lymmo/lymmo-history.stml

[36] Ibid

[37] *LYMMO Downtown Circulator*. City of Orlando. Accessed Jan. 21. https://beta.orlando.gov/Parking-Transportation/Public-Transit/LYMMO

[38] *LYMMO*. LYNX. Accessed Jan. 21. https://www.golynx.com/plan-trip/riding-lynx/lymmo/

[39] *LYMMO Bus Rapid Transit Downtown Circulator*. Nashville Area Metropolitan Planning Organization, North East Corridor Mobility Study. Accessed Jan. 21. http://www.nashvillempo.org/northeast/LYNX%20LYMMO%20Background.pdf

bus's arrival.[40] At intersections, bus movements are controlled with separate signals to avoid confusion with those for general traffic.

The creation of LYMMO was the culmination of various efforts to provide low-cost or free circulator service in Downtown Orlando as part of broader redevelopment goals for the area. Previous iterations of the circulator included the Meter Eater, which cost 25 cents per ride, and the FreeBee, the City offered fare-free through parking revenues. The City and LYNX also explored developing a street car system, the cost of which led them to pursue a bus-based option and, eventually, the creation of LYMMO.[41] The system cost $21 million to create, with $5.25 million of local funds.[42] The service has been free since its creation, the downtown development board's executive director recently suggested the fare-free service may be revaluated.[43]

Station kiosks, like the one highlighted above, provide LYMMO passengers with real-time arrival information at covered stations. (Source: Google Street View)

ROW in one section of the route includes separate LYMMO lanes and, next to general traffic, dedicated bike lanes in both directions. (Source: Google Street View)

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[40] *LYMMO Bus Rapid Transit Downtown Circulator*. Nashville Area Metropolitan Planning Organization.

[41] *LYMMO BRT: 15 Years Later*. Federal Transit Administration. Accessed Jan. 21. https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Report_No._0042.pdf

[42] *Lynx LYMMO Bus Rapid Transit Evaluation*. Federal Transit Administration. Accessed Jan. 21. https://nbrti.org/wp-content/uploads/2017/05/lymmo-7-03.pdf

[43] *Lynx to make adjustments to downtown Lymmo, other routes in 2019*. Orlando Business Journal. Accessed Jan. 21. https://www.bizjournals.com/orlando/news/2018/12/12/lynx-to-make-adjustments-to-downtown-lymmo-other.html

RIDERSHIP AND REACTION

A 2001 survey found passengers rode LYMMO for purposes one would expect – short trips to work and to run errands around downtown.[44] Many were on board for one to two stops before alighting, with trip times only a few minutes in length. The survey found that, at the time, about 40 percent used the service two or three times a day and more than half of riders did not use any another transit service offered by LYNX. However, more than half of the respondents said LYMMO had improved their overall opinion of public transit.

A survey completed in 2012 found changes in trip purposes among passengers, fewer of whom used the service to reach work. More passengers were using it to reach lunch spots and run errands. More than half of respondents reported using the service more than twice a day. Passengers who reported using it four times a day increased from 13 to 21 percent since 2001. Seventy-six percent of respondents thought LYMMO had reduced congestion in downtown and about 80 percent thought LYMMO had made Orlando a more attractive place to live and work.[45]

Average weekday ridership when the service opened in 1997 was 3,091, which exceeded expectations. Ridership leveled off in 1998 and then began to drop in 2010. Average ridership in 2012 was 3,017. The fluctuation in ridership has been attributed, in part, to a drop in the total number of jobs within a quarter mile of the LYMMO route.[46]

A 2003 evaluation found the average weekday speed of the LYMMO was 9 mph, compared to an average speed of 9.9 mph for its predecessor, FreeBee, which operated without the benefit of many of the features of the current service. The evaluation found that LYMMO would likely run much slower without the features, however, because it had more stops and higher ridership, which increased station dwell time compared to FreeBee. LYMMO also stops at each station regardless of whether a passenger has requested a stop.[47]

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[44] *Lynx LYMMO Bus Rapid Transit Evaluation*. Federal Transit Administration.

[45] *LYMMO BRT: 15 Years Later*. Federal Transit Administration.

[46] Ibid

[47] *Lynx LYMMO Bus Rapid Transit Evaluation*. Federal Transit Administration.

LYMMO's current service map. The dedicated lanes are located primarily along the Orange Line along Magnolia Avenue. (Source: LYNX)

ORLANDO LYMMO CASE STUDY

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	4 routes (60-63) daily Ridership = 2,530 (FY18)
	Transit Mode Share	97% Private transport, 2% public transport
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	Ranging from 5-7 min to 20 mins 185 trips (loops) Monday–Thursday, 200 trips Friday, 85 trips Saturday, and 65 trips Sunday
	Transit Signal Priority	LYMMO includes Intelligent Transportation Systems elements: transponders to track bus locations and timepoints, kiosks at stations, and signal priority.
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	Commercial and Office spaces
	Context Classification/ Complete Streets	
	Parking/Curb space	Parking not allowed
	Accessibility	35,807 jobs within ¼ mile in 2010
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	3 lanes. One Way for mixed traffic. One or Two ways for bus depending on the locaiton
	Lane Width	12' Dedicated lane with physical barrier (one way) 10'6" Dedicated lanes with physical barrier between Bus lanes in two directions and between bus lane and mixed traffic
	Intersection Design	Separate logo for signs at stops
	Separation of traffic	Separate lane including extensive signage and pavement painting
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	$21 million (50% federal, 25% state, 25% local) 1996 Funded by the City of Orlando's Downtown Development Board and Parking Division. Annual Operating cost $ 2.25 Million (FY-18)
	Project Length	3 miles (downtown only)

BALTIMORE


Baltimore bus-only lanes created dedicated right-of-way for transit along curbs and adjacent to street parking (Source: Baltimore Sun)

Baltimore introduced dedicated bus lanes in May 2017 as part of a broader overhaul of the city's transit service. The Maryland Transit Administration (MTA) added the lanes on high-frequency bus routes where the newly dedicated right-of-way could carry the same number of people as an adjacent general-use lane.[48]

The 5.5 miles of dedicated right-of-way includes lanes that run along curbs and adjacent to on-street parking. One section converts to bus-only during peak evening travel times only. Despite issues with prohibited vehicles occasionally blocking the bus lanes, MTA points to improved travel times for transit riders on routes using the lanes and a decline in bus-related accidents systemwide as evidence of their success.

BACKGROUND

Baltimore has long had bus-only lanes on two downtown thoroughfares, Lombard and Pratt Streets. These dedicated lanes were created in 2009 but often went unenforced and ignored by most drivers. As part of the region's transit system reorganization, branded BaltimoreLink, a red surface treatment was added to these lanes to distinguish them from general-use lanes, aiding in enforcement and compliance. At the same time, dedicated bus lanes were implemented on six other streets using the same red surface treatment.[49,50]

The overhaul created a total of nine bus-only lanes in downtown. Most of the lanes run curbside or adjacent to parking, except for a portion of Charles Street, where a parking and right-turn lane converts to bus-only from 4 to 6 p.m. on weekdays. The lane is unpainted but marked with street markings and signs.[51]

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[48] *New Dedicated Baltimore Link Bus Lanes Coming to Downtown Baltimore Starting Week of May 15, 2017.* Baltimore City Department of Transportation. Accessed Jan. 25. https://www.baltimoresun.com/business/bs-md-mta-bus-cameras-20180301-story.html

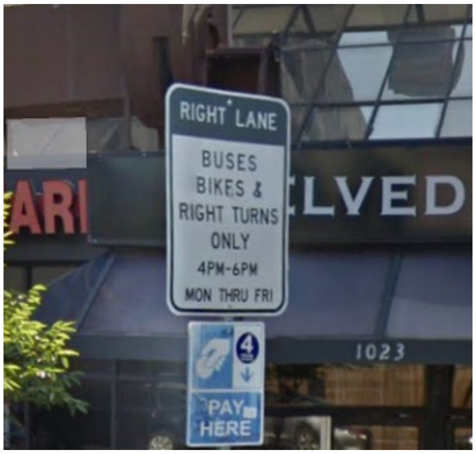
[49] *It's No Red Line, But These New Transit Lanes Will Speed Up Trips for Baltimore Bus Riders.* Streets Blog USA. Accessed Jan. 25. https://usa.streetsblog.org/2017/05/16/its-no-red-line-but-these-new-transit-lanes-will-speed-up-trips-for-baltimore-bus-riders/

[50] *Drivers warned to stay out of Baltimore's new bus lanes.* WBAL-TV. Accessed Jan. 25. https://www.wbaltv.com/article/drivers-warned-to-stay-out-of-baltimore-s-new-bus-lanes/7148528

[51] *Dedicated Bus Lanes Workshop.* Maryland Department of Transportation. Accessed Jan. 25. https://mta.maryland.gov/baltimorelink/images/library/dedicated_lanes/dedicated_bus_lanes_boards_web_2016.pdf

The more than five miles of red lanes cost MTA approximately $5 million to paint, which was part of the $135 million system reorganization.[52] Besides decreasing transit travel times, MTA described the goals of implementing the lanes as improving safety, making transit a more attractive transportation option, and supporting the vibrancy of downtown.

To select streets for the project, MTA evaluated 25 downtown streets with frequent local bus service. The potential streets were narrowed to those with high-frequency service, defined as more than 18 buses per hour. The streets were further narrowed by identifying those where the number of potential passengers that would be carried in a bus-only lane would be more than those in an adjacent general-use lane. For example, MTA noted that the Lombard Street bus lane could move 1,000 riders per hour compared to 700 people in an adjacent car lane.[53]



A sign notifies drivers that the right lane of Charles Street converts to bus-only at peak travel times. (Source: Google Street View)

Bicycles, emergency vehicles, and cars maneuvering into parallel parking spaces along the route can use the lanes. While all other vehicles are prohibited, including taxis, ridesharing vehicles, and loading vehicles, drivers may enter them to make right turns about a half block before reaching an intersection. Areas where turning vehicles can mix with buses are marked with dashed red paint.[54]

The dedicated bus lanes and BaltimoreLink project were initiated after plans for the Red Line light rail project ended. BaltimoreLink, announced in 2015, also included the introduction of signal prioritization technology for transit vehicles on certain routes, with some overlap between TSP and dedicated lanes improvements.[55]

RIDERSHIP AND REACTION

In the month after the implementation of BaltimoreLink, ridership systemwide fell approximately 23 percent, but the system has since rebounded. In May 2018, riders took 5.9 million trips. That month, average weekday trips stood at 226,102, with 125,332 trips per Saturday, and 81,817 per Sunday or holiday.[56] While ridership numbers specific to the dedicated bus lanes is not readily available, MTA has said the newly-painted lanes

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[52] *New Dedicated BaltimoreLink Bus Lanes Coming to Downtown Baltimore Starting Week of May 15, 2017*. Baltimore City Department of Transportation.

[53] *It's No Red Line, But These Transit Lanes Will Speed Up Trips for Baltimore Bus Riders*. Streets Blog USA

[54] *Dedicated Bus Lanes Workshop*. Maryland Department of Transportation.

[55] *It's No Red Line, But These Transit Lanes Will Speed Up Trips for Baltimore Bus Riders*.

[56] *One year of BaltimoreLink bus system: Ridership bounces back, reliability still falls short*. Baltimore Sun. Accessed Jan. 25. http://www.baltimoresun.com/news/maryland/baltimore-city/bs-md-baltimorelink-one-year-20180608-story.html

on Pratt and Lombard Streets have reduced bus travel times up to 25 percent.[57] After the broader system changes, bus accidents dropped 20 percent and bus-related complaints dropped 49 percent.[58]

Enforcing the bus-only lanes has been an issue. A year after their introduction, riders complained about cars and trucks blocking the bus lanes, forcing buses to wait and/or re-enter adjacent mixed-traffic lanes.[59] In the first half of 2018, MTA police issued 277 citations and 149 warnings for bus lane violations. In the same time period, they also handed out 881 tickets for parking in bus lanes or blocking bus stops. An average 600 citations for parking in bus lanes or at bus stops are issued per month.[60] The violations prompted lawmakers to propose enforcement using cameras.[61] Drivers can face a $90 fine and a point on their license for parking or driving in the dedicated bus lanes.[62]

Dedicated Bus Lanes

The Dedicated Bus Lanes on Pratt and Lombard Streets are designed to improve the speed and reliability of transit service through downtown Baltimore.

ONLY buses, school buses, bicycles, and emergency vehicles may use the Dedicated Bus Lanes at all times.

Everyone may enter the dashed portions **ONLY** to make a right turn at the next intersection.

Violators will receive a $90 fine and 1 point on their license.

For more information about how to operate in the dedicated bus lanes go to: **http://transportation.baltimorecity.gov/dot-divisions/transit**

Additional dedicated bus lanes are proposed for several other downtown streets where bus riders comprise a large share of the traffic on the street. To learn more about the proposed lanes and provide comment please go to **http://baltimorelink.com/infrastructure/dedicated-lanes-tsp** or write to **DedicatedBusLanes@mta.maryland.gov**

A notice distributed by transit agencies warning drivers not to block bus-only lanes. (Source: BaltimoreLink.com)

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[57] *Tired of scofflaws, bus riders call on city and MTA for better bus lane enforcement*. Baltimore Fishbowl. Accessed Jan. 25. https://baltimorefishbowl.com/stories/tired-of-scofflaws-bus-riders-call-on-city-and-mta-for-better-bus-lane-enforcement/

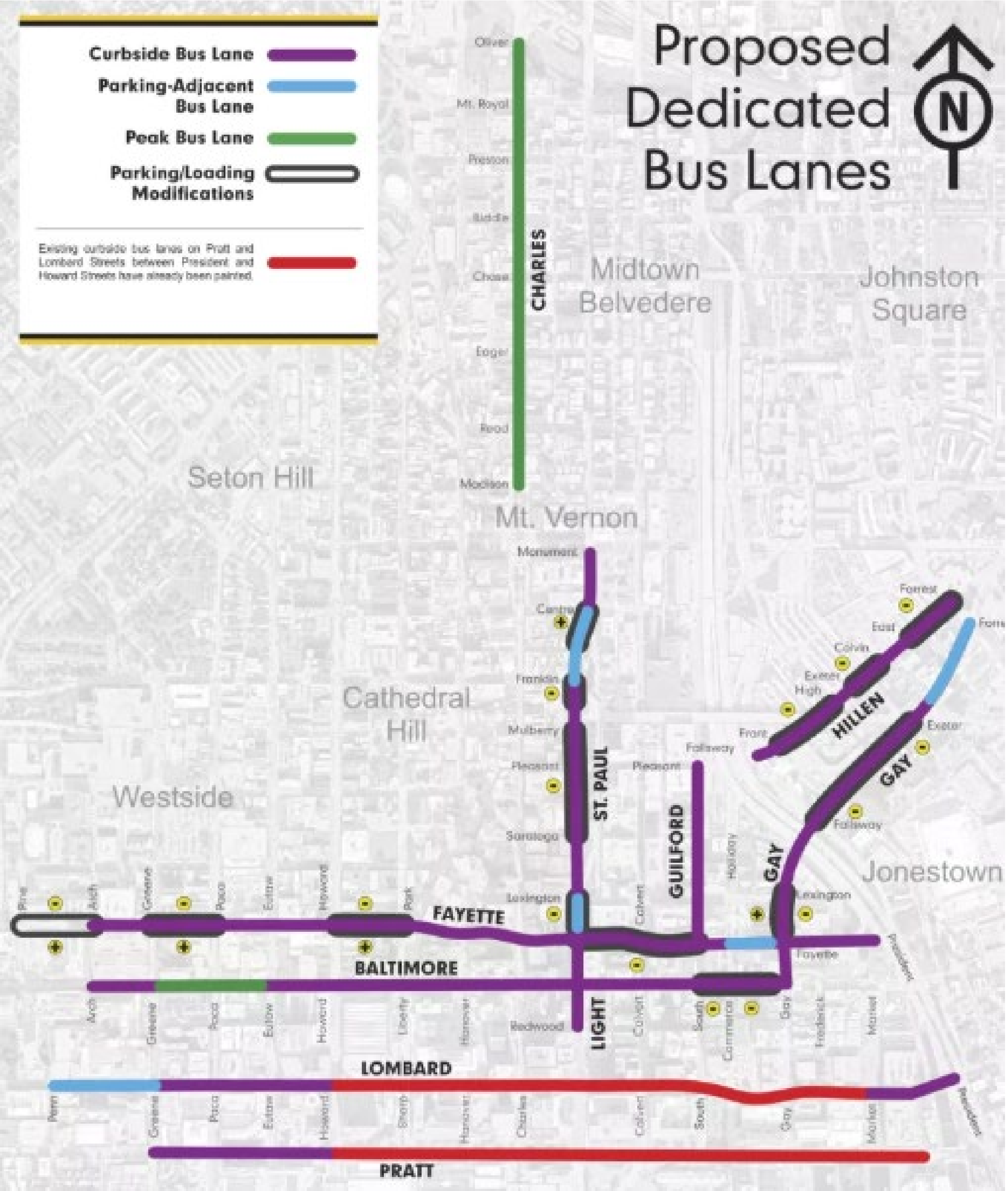
[58] *One year of BaltimoreLink bus system: Ridership bounces back, reliability still falls short*. Baltimore Sun.

[59] Ibid

[60] Ibid

[61] *Bill proposes surveillance cameras to keep motorists out of Baltimore's bus-only lanes*. Baltimore Sun. Accessed Jan. 25. https://www.baltimoresun.com/business/bs-md-mta-bus-cameras-20180301-story.html

[62] *Drivers warned to stay out of Baltimore's new bus lanes*. WBAL-TV.



A map of bus-only lanes in downtown Baltimore (Source: Streets Blog USA)

BALTIMORE BUS LANES CASE STUDY		
Topic Area	**Indicator**	**Findings**
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	> 1,000 per hour
	Transit Mode Share	
	Traffic Volume	34,500 AADT (2016) on W Lombard St 5,300 AADT (2016) on W Baltimore St
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	More than 18 buses per hour (multiple routes)
	Transit Signal Priority	Yes
	Person/Vehicle Delay	
	Average Travel Speeds	<9 mph Before
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	Downtown (No planned land use changes)
	Context Classification/ Complete Streets	
	Parking/Curb space	Parking and loading locations changes vary along the corridor.
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	3 types of Bus lanes Curbside, Parking-Adjacent, Peak-Only,
	Lane Width	
	Intersection Design	
	Separation of traffic	Shared by MTA buses, Charm City Circulator, other buses/shuttles, right-turning vehicles (for ½ block in advance of turn), emergency vehicles, bicycles, cars while parallel parking in adjacent on-street parking
Other	Safety	MTA reports a decline in bus-related accidents resulting from the dedicated bus lanes
	Enforcement	MTA Police can issue moving violations wherever MTA provides service.
	Maintenance	
	Cost	
	Project Length	By the end of 2017 nearly 5.5 lane miles of dedicated bus lanes were in place, with 4.9 mi of full-time lanes with red paint (methyl methacrylate) and appropriate signing and markings, and 0.5 mi of peak-only lanes with signage and pavement markings but no paint.

ALBUQUERQUE

Albuquerque's Bus Rapid Transit, also known as ART, is a BRT line planned to serve 13.5 miles of Central Avenue, the main east-west thoroughfare of the city. Construction of BRT treatments, included dedicated running way, was completed in November 2017. However, full implementation has been stalled while the city resolves operational issues.

Buses are scheduled to arrive every 7 to 8 minutes between 6:30 a.m. and 6:30 p.m. and every 15 minutes at other times. The service will run on segregated, exclusive, median bus lanes throughout the corridor, except in one-way sections in downtown, where they will run on the leftmost lane.

This is the only line in the country to have a BRT Gold standard certification, as it has all the features of a full-fledged BRT: dedicated, BRT-only bus lanes; level boarding stations every half a mile in the dense areas; off-board ticketing; and transit signal priority. It also includes features like High-intensity Activated Crosswalk beacons (HAWK) which allows pedestrians to access the stations safely. The projected daily ridership for ART is 15,750.

The rollout of ART has been delayed due to several problems with the electric vehicles the service was supposed to utilize. As recently as fall 2017, Albuquerque's mayor announced the city was returning 15 of the ART vehicles to their manufacturer because they turned out to have a shorter than expected battery life, limiting the number of miles they could travel. The vehicles ran about 175 miles between charges, 100 fewer miles than promised. The city is now planning to operate ART with diesel- or gas-power vehicles instead.[63]

An example of an electric bus like the models initially planned for ART. The city is now planning to use gas or diesel buses due to problems with battery life. (Source: City of Albuquerque)

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[63] *Albuquerque's Groundbreaking Bus Project Stalled.* Streets Blog USA. Accessed Feb. 17. https://usa.streetsblog.org/2018/11/21/albuquerques-groundbreaking-bus-project-stalled/

ALBUQUERQUE (ART) CENTRAL AVENUE CASE STUDY

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	15,750 (projected) 12,075 (2017) on the corridor including the slow version of the bus 14,000 based on the consultant's website
	Transit Mode Share	8.8 miles exclusive BRT out of total of 17 miles
	Traffic Volume	ADT 18,000 to 38,000 on Central Avenue Corridor 2017
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	Albuquerque Rapid Transit promises to improve travel time by 15% and on-time performance by 20-25%.
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	Peak 7 min Off-Peak 15 min
	Transit Signal Priority	Yes
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	Mostly commercial on Central Ave
	Context Classification/ Complete Streets	
	Parking/Curb space	18 parking spaces added throughout the corridor
	Accessibility	Line connects 32 of 37 bus routes
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	2 bus lanes + 2 mixed traffic lanes + 2 parking lanes + sidewalks
	Lane Width	12' BRT lanes in segregated sections
	Intersection Design	
	Separation of traffic	Previously: Non-segregated rapid bus in mixed traffic Final: 8 miles of segregated median running BRT
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	$119 million ($ 100 million federal funding)
	Project Length	9 miles

CLEVELAND

Source: National Association of City Transportation Officials

HealthLine is a 7.1-mile BRT corridor connecting Cleveland's largest regional employment areas. It runs along Euclid Avenue, connecting University Circle to downtown and extending east to the Louis Stoke Station at Windermere. The buses operate in dedicated median lanes beginning at E. 105th Street in the University Circle area and west to downtown.

Since opening in October 2008, HealthLine has served more than 44 million customers. Its annual ridership has increased about 60 percent compared to the Number 6 bus line, the previous service. The Number 6 route was RTA's highest ridership bus line before it was replaced by HealthLine. More than $9.5 million in economic development along Euclid Avenue has been attributed to the HealthLine. [64]

The route takes an average of 44 minutes to travel, about three minutes faster than the line it replaced, according to a 2010 news report based on data provided Greater Cleveland Regional Transit Authority (RTA).[65] Though HealthLine was initially designed with signal priority to allow buses to move ahead of traffic at intersections, it's unclear to what extent the system is currently used. A member of RTA's Citizen Advisory Board stated that the city turned off the signal priority soon after HealthLine launched due to complaints about delay.[66]

HealthLine's fare enforcement practices have faced scrutiny since the route's launch, with changes impacting wait times for riders. The service initially allowed riders to pay their fare before boarding and enter through any door, which decreased station dwell time. To enforce fare payment, police officers would stop buses at random to check fare cards. The practice was ruled unconstitutional in 2017 by a Cleveland municipal judge.[67] After the ruling, police officers began checking fares as riders boarded vehicles.[68]

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[64] *RTA's HealthLine -- the world-class standard for BRT service*. Greater Cleveland Regional Transit Authority. Accessed Feb. 8, 2019. http://www.riderta.com/healthline/about

[65] ibid., and *HealthLine Buses Moving Slower Than Expected on Euclid Avenue*. Cleveland Plain Dealer. Accessed Feb. 18, 2019. http://blog.cleveland.com/metro/2010/07/healthline_buses_moving_slower.html

[66] *The Ridiculous Politics that Slow Down America's Best BRT Route*. Streets Blog USA. Accessed Feb. 18, 2019. https://usa.streetsblog.org/2014/06/12/the-ridiculous-politics-that-slow-down-americas-best-brt-route/

[67] *Cleveland Police Enforcement of Transit "Proof-of-Payment" Ruled Unconstitutional.* Streets Blog USA. Accessed Feb. 18, 2019. https://usa.streetsblog.org/2017/11/02/cleveland-police-enforcement-of-transit-proof-of-payment-ruled-unconstitutional/

[68] *Riders fault HealthLine's new method of checking tickets*. Cleveland Plain Dealer. Accessed Feb. 18, 2019. https://www.cleveland.com/metro/index.ssf/2017/11/riders_fault_healthlines_new_method_of_checking_tickets_photos.html

CLEVELAND HEALTH LINE CASE STUDY

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	60% above former Route 6, which it replaced
	Transit Mode Share	
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	3 minutes faster running time than former Route 6 (44 minutes observed time)
	Transit Service Frequency	10 minutes on-peak, 10-15 minutes off-peak
	Transit Signal Priority	In place but deactivated due to concern over motorist delays at intersections.
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	Eastern terminus near Case Western Reserve University and Cleveland Medical Center; Western terminus in Downtown Cleveland. Line has spurred substantial (re)development along Euclid Ave.
	Context Classification/ Complete Streets	
	Parking/Curb space	
	Accessibility	Median station access via crosswalks
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	Single lane for auto traffic in each direction.
	Lane Width	
	Intersection Design	Median running lanes requires separate signal phases for buses and left-turning vehicles
	Separation of traffic	Exclusive median running bus lane; separate bike lanes on right shoulder
Other	Safety	
	Enforcement	Fare enforcement by police as riders board.
	Maintenance	
	Cost	
	Project Length	7.1 miles

EUGENE (OR)

Source: Metro Magazine

The Emerald Express, or EmX, is a Bus Rapid Transit system serving the cities of Eugene and Springfield in Oregon. Lane Transit District, the public transit authority of Lane County, operates the system.

EmX comprised of three sections/lines named Green, Gateway, and West Eugene that cover 28 miles:

- The Green line began service in January 2007. The line replaced route 11 that previously ran along the corridor. Buses run at a frequency of 10 to 20 minutes on weekdays between 6 am and 11 pm. Rush hour travel time was reduced from 22 minutes to 16 minutes on the Green line corridor.
- The Gateway corridor started operation in January 2011, connecting EmX to Gateway mall.
- The West Eugene corridor, the latest piece, began operation in September 2017.

All the BRT vehicles are given transit signal priority though a ground loop signaling the traffic control system. Buses run on dedicated corridors on the median for about 60 percent of the route and in mixed traffic for the remaining 40 percent.

The dedicated, physically separated bus lanes in this project, for the most part, are not paved for their entire width. They are paved where the tires touch the surface and the gaps are landscaped with turf. This treatment may make it difficult or impossible for other vehicles (emergency vehicles, e.g.) to use the restricted lanes. In sections where the segregated lanes are not physically separated from mixed traffic, the buses still run in the left lane, and stations are located in the median. The dedicated lanes are marked and labeled as bus-only. None of the dedicated bus lanes are painted red, but their distinctive design likely provides an enforcement benefit similar to that associated with red surface treatments. On some one-way streets, the bus lane is in a center exclusive lane, allowing right-turning vehicles to utilize the curbside lane.

Source: The Transport Politic

EUGENE (OR) EMERALD EXPRESS CASE STUDY

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	6,000 average (weekday)
	Transit Mode Share	Existing - 87% Auto, 4% Transit, 9% Bike/walk
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	10 to 15 minutes weekdays; 15 to 30 minutes evenings and weekends
	Transit Signal Priority	Yes
	Person/Vehicle Delay	
	Average Travel Speeds	Operating speed - 17 mph
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	This corridor includes a contiguous MUP all along its path. Sidewalks and bike lanes in the downtown section + 2 x 2 lane roadway on either side.
	Parking/Curb space	
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	6 lanes in the two-way section 1 -2 lanes in the one-way section
	Lane Width	12'6" at curbside sections 2 x 11' at median running sections
	Intersection Design	Separate signals for buses at all signalized intersections
	Separation of traffic	6 miles of segregated lanes (bus only) + 3 lanes of mixed traffic
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	Side Lane BRT (BRT Elements and related improvements) - $170 Million Annual M&O = $49,500,000
	Project Length	6 miles of segregated lanes (Curbside & Median) + 3 miles of mixed traffic

JACKSONVILLE

The South East Corridor BRT is operated as Route 107 (Blue line) by Jacksonville Transportation Authority. The line opened in 2016, one year after its non-BRT express bus route 102 (or the Green line). The Blue line is a 11.1-mile long route with 1.5 miles of bus priority lanes along the downtown portion of the corridor and along certain sections of Kings Ave. Buses run at a frequency of 10 to 15 minutes. In order to reduce dwell time at stops, off-board ticket vending machines have been installed at all stops.

Four one-way streets in downtown Jacksonville have their right lane designated as a bus priority lane. The lanes are marked by a solid white line rather than a red surface treatment. Cars are not allowed in bus lanes during peak hours (6 a.m. to 9 a.m. and 3 p.m. to 6 p.m. on weekdays). In select locations, the bus lane may be used by cars for right turns. Emergency vehicles, bicycles, and school buses can use the bus lanes at any time. A queue jump for buses is located at the intersection of W. Forsyth Street and N. Jefferson Street. Buses have transit signal priority at all intersections.

The Kings Avenue bus lanes are denoted by a solid white line. Cars making right turns are allowed to use the bus lanes at some intersections. Restrictions apply only during peak commuting hours. (Source: Google Street View)

JACKSONVILLE (FL) SOUTHEAST CORRIDOR CASE STUDY

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	8,900 (split between the BRT only sections of 4 different routes)
	Transit Mode Share	
	Traffic Volume	AM peak 2012: between 200 and 2,907 throughout the corridor (mostly above 1,000)
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	10 - 15 mins
	Transit Signal Priority	Yes + Queue Jump Lanes
	Person/Vehicle Delay	
	Average Travel Speeds	24 - 28 mph
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	
	Accessibility	Minority population - 66.42% Low income population = 14.42% Pop over 64 = 9% (study area)
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	
	Lane Width	
	Intersection Design	
	Separation of traffic	re-designation of existing pavement currently striped for parking as bus-only lanes
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	
	Project Length	11.1 miles 8 stops

LOS ANGELES

With 93,000 weekday bus boardings, Wilshire Boulevard is a critical transit corridor in Los Angeles County. A section of it was selected to be implemented as peak hour transit priority lanes to improve bus travel time reliability, a 3.5-mile alignment in operation since July 2013.

Only buses and bicyclists can use the dedicated lanes during peak weekday travel times of 7 am to 9 am and 4 pm to 7 pm. The Wilshire BRT Project cost $31.5 million, with a federal share of $23.3 million and the city of Los Angeles and the Los Angeles County Metropolitan Transportation Authority contributing a $8.2 million local match.[69,70]

Source: Los Angeles Magazine

At certain intersections, general traffic can use the bus-only lanes to make right turns during peak travel times (7 am to 9 am and 4 pm to 7 pm). According to news reports, many drivers use the bus-only lanes to proceed forward through an intersection rather than make a right turn, creating conditions that block transit vehicles.[71]

The Los Angeles County Metropolitan Transportation Authority places enforcement of the exclusive bus lanes among its priorities in its strategic plan. Its aim is to achieve a minimum average speed of 18 mph on rapid bus routes. The operator will also study converting service like that provided on Wilshire Boulevard to bus-rapid transit.[72]

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[69] *Wilshire Bus Rapid Transit (BRT) Initial Study/Environmental Assessment*. Los Angeles County Metropolitan Transportation Authority. Accessed Feb. 8. http://media.metro.net/projects_studies/wilshire/images/Fact%20Sheet%202.pdf

[70] *Wilshire BRT Dedicated Bus Lane Opened, June 5, 2013*. Los Angeles County Metropolitan Transportation Authority. Accessed Feb. 8. https://www.metro.net/projects/bus-rapid-transit-studies/dedicated-bus-lane/

[71] *Law-Breaking Drivers Disrespecting New Wilshire Boulevard Bus-Only Lanes*. Streets Blog USA. Accessed Feb. 18. https://la.streetsblog.org/2015/05/19/law-breaking-drivers-disrespecting-new-wilshire-boulevard-bus-only-lanes/

[72] *Metro Strategic Plan*. Los Angeles County Metropolitan Transportation Authority. Accessed Feb. 18. http://libraryarchives.metro.net/DB_Attachments/Report_Metro%20Strategic%20Plan_DRAFT%20v5_2018-4-2.pdf

LOS ANGELES WILSHIRE BOULEVARD CASE STUDY

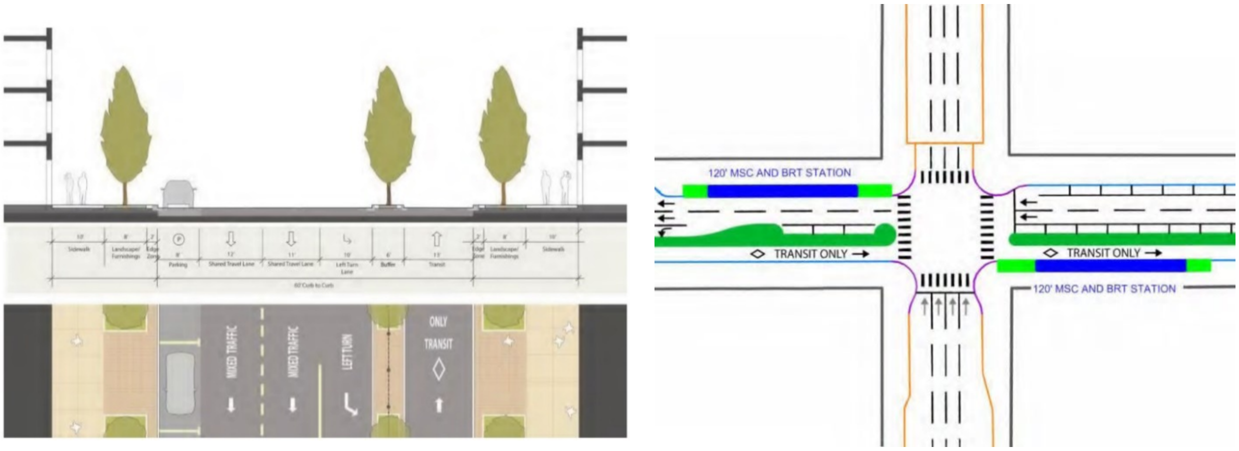
Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	13,000 per weekday (route 20) 27,340 per weekday (route 720 express)
	Transit Mode Share	
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	3 minutes (peak) to 10 mins (off peak)
	Transit Signal Priority	Yes
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	11 parking spaces removed
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	
	Lane Width	
	Intersection Design	
	Separation of traffic	Right lane reserved for buses on weekday peak hours. Solid white line with slight difference in shade than the adjacent pavement to demarcate bus only lanes.
	Access management	Buses and Bikes are allowed. Right turning cars are allowed at intersections
Other	Safety	
	Enforcement	Violations by motorists have been noted, especially at intersections (through movements instead of right turns)
	Maintenance	
	Cost	$31.5 million ($23.3 million federal share)
	Project Length	3.5 miles

OMAHA

ORBT, or Omaha Rapid Bus Transit, is an 8.5-mile bus priority corridor utilizing the Dodge Street (US 6) and Farnam Street corridors. Planning for ORBT is being led by Metro, the city's public transport authority. The line intersects most other bus lines of Omaha, providing a rapid-transit axis with high connectivity to local fixed-route services. The ORBT alignment is planned to include Business Access and Transit (BAT) lanes east of 30th Street and a transit signal priority (TSP) corridor in a less dense area west of 30th Street. ORBT route is expected to operate at 10-minute headways and adopt stop spacing standards that minimize the number of stops made by vehicles at stations and maintain faster average travel speeds.[73]

Implementation may include a contra-flow transit lane on Farnam Street in central Omaha, as specified in the City's TIGER grant application (2014). The contra-flow transit lane is a new design solution for Omaha and presents operational concerns at intersections. However, Metro expects the contra-flow lane will enhance system cohesion and economic development along the Farnam Corridor compared to an alternative implementation that would utilize standard curbside lanes along the Farnam/Harney one-way couplet. Strategies for addressing the issues raised by the contra-flow facility are not addressed in detail in the TIGER grant application, but the approach illuminates some of the motivations and risks associated with contra-flow transit lanes as a design option for one-way streets.[74]

Metro received a $14.9 million TIGER grant in 2014 from the US Department of Transportation for the project as well as substantial contributions from several private sources. The total projected capital cost of ORBT is $30.5 million,[75] suggesting a typical cost of about $3.5 million per mile. Planning for ORBT began before 2014. Construction was expected to start in Fall 2018 but had not commenced at the time of this report.



The ORBT project may include a contra-flow transit lane on a one-way street. The 2014 TIGER application provides diagrams illustrating the location and basic design of the contra-flow lane.

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[73] *Meet Omaha's new, faster bus to downtown: ORBT.* Omaha World-Herald. Accessed Feb. 18. https://www.omaha.com/news/metro/meet-omaha-s-new-faster-bus-to-downtown-orbt/article_1b0a5ede-82aa-11e7-bd5a-c3adf3e8d23c.html

[74] *Central Omaha Bus Rapid Transit – Connecting the Dots*. Transit Authority of the City of Omaha. Accessed Feb. 18. http://www.ometro.com/wp-content/uploads/2017/08/TIGER-Application.pdf

[75] *ORBT FAQs*. Transit Authority of the City of Omaha. Accessed Feb. 8. http://www.rideorbt.com/faq/

OMAHA ORBT CASE STUDY		
Topic Area	**Indicator**	**Findings**
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	Existing Route # 2: 1,750 daily boardings in 2015 (busiest in the system)
	Transit Mode Share	
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	10 mins during rush hour
	Transit Signal Priority	Yes. West of 30th St (non-downtown) only
	Person/Vehicle Delay	Construction of the BRT system will shorten travel along the corridor by 15.7 minutes.
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	
	Accessibility	Sixteen percent of households within one-quarter mile of the proposed BRT route do not have access to a vehicle and will benefit directly from increased access to jobs, activity centers, and medical facilities.
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	4 lanes + parking (one direction)
	Lane Width	10'6"
	Intersection Design	
	Separation of traffic	Business Access & Transit (BAT) lanes for 3.3 miles in downtown Omaha. Renders show red paint used to designate segregation.
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	$30.5 million ($15 million TIGER grant)
	Project Length	8.5 miles

WASHINGTON DC

In order to improve travel time reliability for buses plying along the most congested stretch of Georgia Avenue, a four-block (0.3 mile) section between Florida Avenue and Barry Place NW was reconfigured to include a bus priority lane.

This stretch is used by Metrobus routes 70 and 79, which carry more than 20,000 passengers from downtown Washington to Silver Spring, MD. This treatment is a part of a larger plan to overhaul the layout and reduce congestion along the entirety of Georgia Avenue.

This short section has included a transit priority lane since 2016. The right lane along the corridor is painted red with a double white line separating it from general-use lanes. The lane is designated primarily for use by buses (private or public). However, other vehicles can utilize the lanes, including emergency vehicles, paratransit vehicles, taxicabs, and bicycles as well as right turning cars at intersections.

While not all cities allow bicyclists in bus-only lanes, the Georgia Avenue red lanes feature shared-lane markings, as pictured above. The dashed white line indicates where drivers may enter the lane to make a right turn. Parking is not allowed along the corridor. Vehicle restrictions along the segment are enforced manually by officials, and violations can incur a $200 fine.

This section was implemented as a pilot or demonstration project, and the experience will be used to plan and implement similar transit priority treatments on other corridors in DC. There are plans to extend this section and implement a similar design on 14th St NW.

Source: Greater Greater Washington

WASHINGTON DC GEORGIA AVENUE CASE STUDY		
Topic Area	**Indicator**	**Findings**
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	Buses passing through this corridor carry more than 20,000 riders every day.
	Transit Mode Share	
	Traffic Volume	Before: 24,900 (2015) After: Not available (2017)
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	
	Transit Signal Priority	
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	Parking not allowed
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	Total ROW = 75'
	Lane Width	2 curbside Red lanes (12') + 2 mixed traffic lanes
	Intersection Design	
	Separation of traffic	Allowed in Bus lane: transit Buses, tour buses, charter buses, school buses, taxis, bikes, paratransit service vehicles, emergency vehicles, turning vehicles. The dedicated bus lanes are in effect Monday – Saturday between the hours of 7:00 am to 10:00 pm.
Other	Safety	
	Enforcement	Parking and turning movement violations $200. Monitored by officials.
	Maintenance	
	Cost	
	Project Length	0.5 mile

LITERATURE REVIEW

The RED Lanes Study literature review summarizes a broad body of literature on the topic of transit priority lanes and supporting corridor treatments. It synthesizes findings from numerous publications – several being research syntheses themselves – to highlight the major features of RED lanes and key contributors to their success. The literature review augments the real-world experience summarized in the case studies presented above with guidance generated by major research projects, guidebooks, synthesis reports, studies and plans from a variety of North American contexts. As such, the findings of the literature review frame generalized best practices and key considerations for RED lanes planning and implementation, regardless of regional size, transit system characteristics, or other considerations relevant to the selection of peer case studies. The findings address decision-making and planning frameworks for RED lanes, common measures for RED lanes evaluation, design considerations for implementation, and general rules for estimating RED lane benefits and costs.

The publications summarized below are selected from a much larger body of literature, an exhaustive review of which would constitute a significant investment in its own right. Selected articles and reports, however, cover a broad array of topics with clarity and appropriate depth for the purposes of the RED Lanes Study. Moreover, there is substantial cross-referencing across various reports, such that several summarized here capture the content of others not summarized. An additional reading list provided at the end of this section highlights other publications addressing RED lanes and related topics, but which were deemed not essential for the current study in light of the selected publications summarized. Interested readers are encouraged to explore these resources in addition to the selected publications for detailed information on a given RED lanes-related topic.

In the summaries of selected publications provided below, the RED Lanes Information Gathering Concept Matrix has been provided for those that have a comprehensive scope and synthesize research findings on the broad topic of transit priority lanes and related treatments. Other publications are focused on particular topics, such as enforcement, pavement treatments, or planning approaches; summaries of these documents are provided but a populated matrix has not been prepared.

SUMMARY OF KEY FINDINGS FROM LITERATURE

Before summarizing selected publications and highlighting their relevance to and guidance for RED lanes planning and implementation, this section distills the common themes and findings from the complete body of literature for brief summarization on specific topic areas, including:

- Decision-making frameworks for RED lanes
- Common metrics and criteria
- Design and operational considerations
- Costs and benefits of RED lanes

DECISION-MAKING FRAMEWORKS FOR RED LANES

There is a strong consensus among recent publications supporting a comprehensive approach in decision-making around the establishment of transit-supportive facilities, including transit exclusive and priority lanes. While the "warrants" for bus lanes first established in early TCRP publications (1970s) are still used, more recent publications recommend expanding the narrow focus from transit vehicle volumes and ratios of passenger throughput by mode to more comprehensive considerations, including policy-driven approaches. This trend in the literature is perhaps best summarized in TCRP Report 183: [76]

> *"A review of transit-supportive roadway strategies implemented by 52 transit agencies in the United States and Canada (Danaher 2010) found that nearly all considered multiple factors when evaluating strategies and did not apply the NCHRP Report 155 warrants."*

In providing guidance on decision-making criteria for transit lanes, TCRP 183 proposes using four criteria, identified in AASHTO's Transit Design Guide (2014)[77] in combination with four community factors developed by TCRP Report 183. The four factors from the AASHTO Transit Design Guide are:

1. *Provide priority to road users using less-polluting, more space- and energy-efficient, and less-costly (to society) travel modes.*
2. *Allocate roadway delay proportionally among all roadway users.*
3. *Protect the public investment in transit service.*
4. *Give an advantage to vehicles that maximize person throughput.*

Intended to supplement the factors above are the following four community considerations developed as part of TCRP Report 183:[78]

1. *Improvements to the community's mobility options.*
2. *Support for the community's long-term economic development vision.*
3. *Support for community goals to promote greater use of non-automobile modes.*
4. *Environmental impacts.*

COMMON METRICS AND CRITERIA

There is no clear consensus for specific thresholds or warrants in selecting potential candidates for transit supportive facilities. TCRP Synthesis 83, which conducted a survey with numerous transit agencies, concludes that: "there are no standard warrants being applied to identify the need for particular treatments." However, several common themes do emerge from the literature as typical factors that should be considered. Indeed, in 2018, the Maryland Department of Transportation concluded in a literature review that, "Though there is no clear consensus on specific performance measures that should be used for selecting streets where dedicated bus lanes may work best, there are some clear considerations that must be considered." [79] Details of these key considerations vary depending on the specific application, location, and publication, but the following common measures/considerations appeared in most of the reviewed literature:

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[76] *TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies*, 2016. https://www.nap.edu/download/21929

[77] *Guide for Geometric Design of Transit Facilities on Highways and Streets*, 2014. https://store.transportation.org/Item/CollectionDetail?ID=133

[78] *TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies*, 2016. https://www.nap.edu/download/21929

[79] *Developing Dedicated Bus Lane Screening Criteria in Baltimore, Maryland.* Transportation Research Record, 2018. https://journals.sagepub.com/doi/abs/10.1177/0361198118797827

- Transit Vehicle Volume
- Person Throughput (by all modes)
- Safety
- Reliability/travel time variability/delay
- Automobile level of service (LOS)
- Physical/spatial considerations:
    - Available right-of-way (ROW)
    - Presence of parking
    - Access implications/access density

Specific examples of metrics developed for identifying and evaluating potential transit lanes are provided in this report in three literature summaries of projects conducted in Tampa, Miami, and Baltimore. Although there is not a consensus in the literature for specific thresholds, these applications provide examples of values deemed appropriate for their respective contexts and are useful as references when framing an approach to evaluating and prioritizing potential transit priority lanes in the CAMPO region.

DESIGN AND OPERATIONAL CONSIDERATIONS

Transit Lane Width

There is a clear consensus among the literature reviewed that the recommended minimum width for a transit lane is 11 feet. In many cases, 12-13 feet is listed as the preferred lane width, and in some cases – especially where the lane is shared with bicyclists – up to 14.5 - 16 feet or more may be warranted.[80] However, as the case study section of this report has shown, there are numerous examples of transit priority lane implementations with narrower widths (sometimes as narrow as 10 feet).

Managing Turns and Shared Uses

The literature is clear that allowing non-transit uses in transit lanes reduces the time savings benefit to transit vehicles. TCRP Report 183 notes that time savings can be reduced by half when right turns are allowed in central business district areas.[81] However, the literature also indicates that the allowance of non-transit users – such as right turns, taxis, and bicyclists – can help build support in a community where transit vehicle volumes are relatively low or physical space allows for use by other modes/vehicles.

Red Surface Treatments

Throughout the literature, there is consensus that red surface treatments are a cost-effective component of transit priority-lane implementation that is effective at reducing violations by motorists or other restricted users. In general, red surface treatments are considered appropriate for full-time transit lanes; it's use for part-time transit priority lanes is less common and generally not recommended. Red can be used to designate either parts of or an entire corridor. It is important to note that because red surface treatments are not included in the MUTCD for the purpose of designating transit facilities, FHWA Interim Approval may be needed before applying red paint to a given corridor. TCRP 183 Appendix D contains information and a template for applying for this approval. [82]

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[80] Ibid

[81] Ibid

[82] *TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies*, 2016. https://www.nap.edu/download/21929

Transit Signal Priority Considerations

Transit Signal Priority (TSP) is widely considered in the literature reviewed to be an appropriate transit-supportive strategy in most urban environments. In general, TSP is most effective in environments where transit vehicles experience delay from congestion, but where congestion is not so severe as to prevent the transit vehicle from taking advantage of the TSP benefit. TCRP Synthesis 83 identified the following criteria as being best suited applications for TSP:[83]

- Level of Service (LOS): D and E
- Volume-to-capacity ratio (v/c): between 0.8 and 1.0

TSP can have an impact on vehicle traffic, especially along busy cross-streets. However, several studies reviewed in this report indicate that impacts are typically minor to negligible.

Enforcement

There is general agreement among the literature reviewed that a mixture of enforcement measures is needed, with an emphasis placed on the most cost-effective measures, such as red surface treatment and automated enforcement. Additionally, publications recommend engaging with all stakeholders involved in transit lane enforcement at all phases of a project.

COSTS AND BENEFITS OF RED LANES

Estimating Benefits

The literature review revealed several methods for estimating benefits form the installation of transit lanes. Perhaps the most widely used is the *Transit Capacity and Quality of Service Manual, 3rd Edition*, which includes the table below for estimating time savings based on several variable. The table shows bus travel times, in minutes per mile, based on different bus treatments and conditions.

Condition	**Bus Lane**	**Bus Lane, No Right Turns**	**Bus Lane with Right Turn Delays**	**Bus Lanes Blocked by Traffic**	**Mixed Traffic Flow**
CENTRAL BUSINESS DISTRICT					
Typical		1.2	2.0	2.5 – 3.0	3.0
Signals set for buses		0.6	1.4		
Signals more frequent than bus stops		1.5 – 2.0	2.5 – 3.0	3.0 – 3.5	3.5 – 4.0
ARTERIAL ROADWAYS OUTSIDE THE CBD					
Typical	0.7				1.0
Range	0.5 – 1.0				0.7 – 1.5

Source: TCRP Research Results Digest 38 (37)
Note: Traffic delays reflect peak conditions

Other methods for measuring benefits identified in this report include observed benefit surveys, which are reported in several of the literature review summaries, including TCRP Synthesis 83.

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[83] *TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic*. Transportation Research Board (TRB), 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

Estimating Costs

This literature review identified several methods for estimating the cost of installing various transit-supportive facilities. The most authoritative source identified in this literature review is TCRP Report 90, which is reprinted in TCRP Synthesis 83. For the conversion of existing to transit only lanes, TCRP 90 estimates capital costs between $50,000 to $100,000 per mile. This estimate includes re-striping and signage. The cost for new transit lanes on urban streets is included in the below, originally published in TCRP 90.

Treatment	Capital Cost
Curb or off-set lanes	$2 to $3 million/lane-mile
Median transitway (bus)	$5 to $10 million/lane-mile
Median transitway (LRT)	$20 to $30 million/track-mile

TCRP 83 also includes Transit Signal Priority (TSP) cost estimates. TCRP 83 notes that signal upgrades can be under $5,000 per intersection if existing equipment can be utilized. When new equipment is needed, costs can be expected in the range of $20,000 to $30,000 per intersection.

PUBLICATION SUMMARIES

TCRP SYNTHESIS 83: BUS AND RAIL TRANSIT PREFERENTIAL TREATMENTS IN MIXED TRAFFIC

Transportation Research Board (TRB), 2010[84]

Report Summary

The purpose of this report is to synthesize all potential transit preferential treatments that have been or could be applied. Treatments reviewed in this report include:

- Roadway Segments: Median transitway, exclusive lanes outside the median area, and limited stop spacing/stop consolidation.
- Spot Locations (Intersections): Transit signal priority (TSP), special signal phasing, queue jumps

This summary focuses on the topics of exclusive lanes outside the median area and TSP.

Decision Framework for Transit Lanes

In making decisions around designating a transit lane, TCRP Synthesis 83 recommends an approach that considers the following questions as a decision-making framework:

1. Is the transit demand high enough to warrant service so frequent that exclusive transit lanes will be well-used and even self-enforcing?
2. Is there adequate roadway right-of-way available to develop a median transitway or added traffic lanes that could be dedicated to transit use?
3. Will the development of exclusive transit lanes still allow adequate local access in a corridor, recognizing that median transitways may block mid-block and unsignalized intersection left-turn access, and curbside transit lanes have to share the lanes with local driveway movements and right turns at intersections?

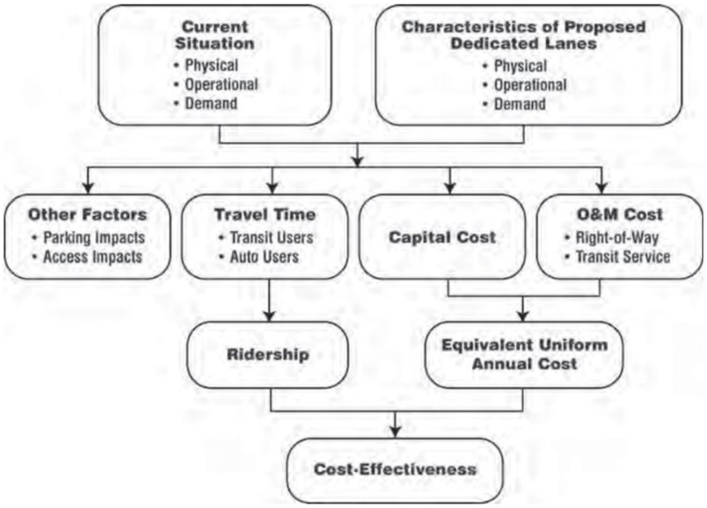

FIGURE 55 Evaluation process for dedicated transit lanes [*Source: TCRP Report 118* (*5*)].

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[84] *TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic*. Transportation Research Board (TRB), 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

In addition, the report identifies a process for evaluating transit lanes from a cost-effectiveness and feasibility perspective. This framework, illustrated in “Figure 55,” was first published in TCRP 118.

Decision Framework for Transit Signal Priority (TSP)

In considering TSP improvements on a corridor, the synthesis report lists six key considerations:

1. Are traffic conditions and transit volumes along a corridor currently within or projected to be within the “operationally feasible” range to successfully implement TSP?
2. Can TSP be implemented without creating unacceptable congestion on cross-streets?
3. Is it possible to implement an extended TSP treatment along a corridor with a median tramway or exclusive transit lanes and, if so, would it provide added benefit to warrant the added cost?
4. Can transit stops be located on the far side of an intersection, or mid-block, so that effective TSP can be provided?
5. Is the existing traffic signal control system capable of accommodating TSP, or are signal hardware and/or software modifications needed?
6. Will automatic vehicle location (AVL) or automatic passenger counters (APC) be integrated with transit vehicles, which will dictate whether conditional or unconditional TSP can be applied?

Similar to the transit lane framework, the report also identifies a decision-making framework for evaluating TSP candidates. This is illustrated below in “Figure 56,” first published in TCRP 118.

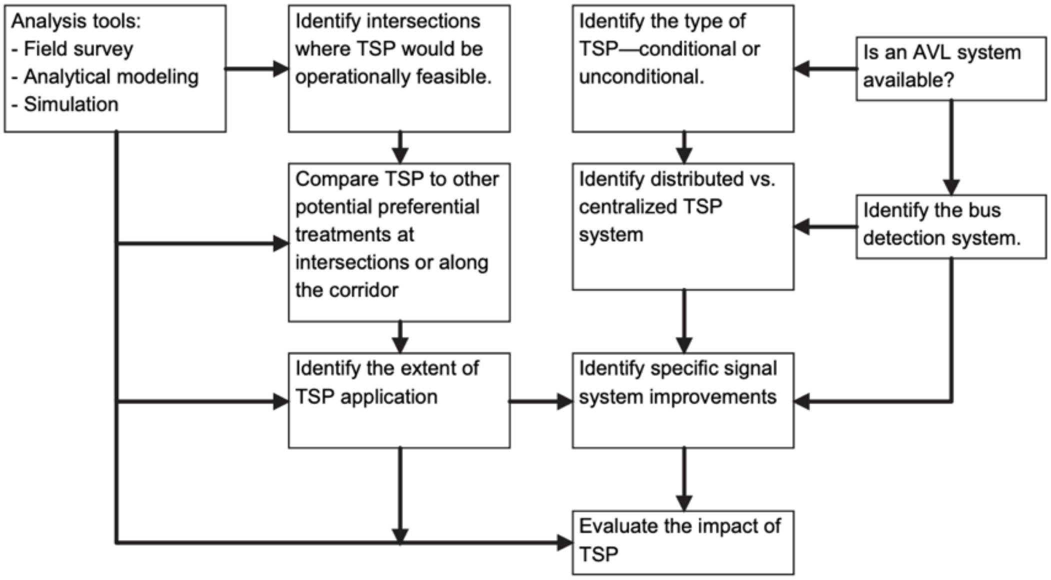

FIGURE 56 TSP decision framework [*Source: TCRP Report 118* (*5*)].

Transit Lane Suitability

As part of TCRP 83, a survey was conducted of transit agencies to identify warrants for transit priority treatments, including exclusive bus lanes. The table below reports survey findings by transit agency. The researchers note that “there are no standard warrants being applied to identify the need for particular treatments.” However, several themes do emerge, including: "ridership, safety, and delay considerations, as well as reliability and level of service.”

Although the survey did not find consensus around thresholds or warrants for transit lanes as applied today, TCRP 83 included a literature review that identified historical warrants used for bus lanes. The table below, adapted from this report, reviews these warrants.

Report	Metric	Proposed Warrants
NCHRP Report 143: Bus Use of Highways— State of the Art (1973)	Transit Vehicles Per Peak Hour	Minimum 60 transit vehicles per hour
	Ratio of riders in transit vehicles to drivers and passengers in automobiles	At least 1.5 times as many transit riders than drivers and passengers
NCHRP Report 155: Bus Use of Highways: Planning and Design Guidelines (1975)	Design Year One-Way Transit Vehicle Volumes Per Peak Hour (existing volumes at least 75% of design year volumes).	Curb bus lanes within central business district (CBD): 20-30 Curb bus lanes outside CBD: 30-40 Report recommends taxis be allowed to use bus lanes when peak hour transit vehicle volumes are less than 60.

Transit Signal Priority (TSP)

TCRP 83 notes that TSP is most effective at intersections with the following conditions:

- LOS most effective where TSP is between D and E, with limited benefits at LOS A through C
- Volume-to-capacity (v/c) ratio: between 0.8 and 1.0

It is noted that v/c conditions over 1.0 have been found to be ineffective, as transit vehicles have been found to be delayed too long to take advantage of the extended green time in the signal cycle.

Cost Estimates for Transit Lanes and TSP

The report highlights cost estimates first identified in TCRP Report 90 (2007). For the conversion of existing to transit only lanes, TCRP 90 estimates capital costs between $50,000 to $100,000 per mile. This estimate includes re-striping and signage. The cost for new transit lanes on urban streets is included in the below, originally published in TCRP 90.

Treatment	Capital Cost
Curb or off-set lanes	$2 to $3 million/lane-mile
Median transitway (bus)	$5 to $10 million/lane-mile
Median transitway (LRT)	$20 to $30 million/track-mile

TCRP 83 notes signal upgrades can be under $5,000 per intersections if existing equipment can be utilized. When new equipment is needed, costs can be expected in the range of $20,000 to $30,0000 per intersection.

Travel Time Savings Estimates for Transit Lanes and TSP

TCRP 83 synthesizes previously published time savings estimates from transit lanes and TSP. These estimates are illustrated below in the following tables from TCRP 83.

Location	**Source**	**Travel time savings (minutes per mile)**
Los Angeles – Wilshire Blvd.	Observed	0.1 – 0.2 (am) 0.5 – 0.8 (pm)
Dallas – Harry Hines Blvd.	Observed	1.0
Dallas – Ft. Worth Blvd.	Observed	1.5
New York – Madison Ave.	Observed	43% (express) 34% (local)
San Francisco – 1st Street	Observed	39%
Highly Congested CBD	Estimated	3 – 5
Typical CBD	Estimated	1 – 2
Typical Arterial	Estimated	0.5 - 1

Source: TCPR Synthesis 83, Tables 20, 27

Location	**% Running Time Saved**	**% Increase in Speeds**	**% Reduced Intersection Delay**
Anne Arundel County, MD	13 – 18		
Bremerton, WA	10		
Chicago, IL – Cernak Road	15 – 18		
Hamburg, Germany		25 – 40	
Los Angeles, CA – Wilshere/Whittier	8 – 10		
Pierce County, WA	6		
Portland, OR	5 – 12		
Seattle, WA – Rainier Ave	8		13
Toronto, ON	2 – 4		

Source: TCPR Synthesis 83, Table 22

TCRP SYNTHESIS 83: BUS AND RAIL TRANSIT PREFERENTIAL TREATMENTS IN MIXED TRAFFIC		
Topic Area	**Indicator**	**Findings**
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	Segment ridership > 100 per day
	Transit Mode Share	
	Traffic Volume	LOS C-D or LOS E-F w/ available ROW
	Non-Motorized Users	
	Person Throughput	Generally, a bus lane is justified when it can be expected to carry as many person trips as an adjacent general traffic lane, though some studies suggest 1.5 times the person throughput of an adjacent lane.
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	Numbers from reports vary: 25 buses per hour in a transit priority lane; 60 buses per hour in an exclusive lane. 60-90 buses per hour for transit-way; 40-60 buses per hour for contraflow lanes (20-30 for a short segment); 10-15 buses per hour for signal preemption, etc.
	Transit Signal Priority	Most effective at LOS D-E conditions with V/C ratios between 0.80 and 1.00. Limited benefit at LOS A-C. V/C > 1.00 may present long vehicle queues that limit the effectiveness of TSP.
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	Parking rarely allowed in bus lanes; offset or interior lanes are recommended to accommodate parking.
	Accessibility	
	Facility Functional/Access Class	Access density < 10 driveways per mile
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	There should be at least 2 lanes available for general traffic in the same direction, when possible.
	Lane Width	11’ minimum width recommended
	Intersection Design	
	Separation of Traffic	
Other	Safety	
	Enforcement	
	Maintenance	
	Cost	TSP can be <$5,000 per intersection if existing software/controller equipment can be used, otherwise $20,000 - $30,000. Conversion of existing lane to bus lane $50,000-$100,000 per mile; $2-$3 million for new construction.
	Project length	

TCRP REPORT 183: A GUIDEBOOK ON TRANSIT-SUPPORTIVE ROADWAY STRATEGIES

Transportation Research Board (TRB), 2016[85]

Report Summary

TCRP 183 is intended to provide guidance around improving bus speed and reliability on streets, with a focus on creating streets designed for all users. The report includes specific strategies, decision making and operational guidance, and recommendations for changes to the Manual on Uniform Traffic Control Devices (MUTCD) intended to help facilitate the implementation of transit supportive designs. This review includes key findings from the report that address transit lanes and transit signal priority (TSP).

Decision Framework

The report proposes a comprehensive perspective in the selection of transit -supportive facilities as opposed to the more narrowly focused warrants developed in the previously published NCHRP 142 and 155. TCRP 183 states that "A review of transit-supportive roadway strategies implemented by 52 transit agencies in the United States and Canada (Danaher 2010) found that nearly all considered multiple factors when evaluating strategies and did not apply the NCHRP Report 155 warrants."

AASHTO's transit design guide, published in 2014, is cited as a recommended framework for identifying transit supportive facilities. This framework encourages the use of multiple decision-making criteria. The AASHTO guide identifies the following four criteria to be considered:

1. Provide priority to road users using less-polluting, more space- and energy-efficient, and less-costly (to society) travel modes.
2. Allocate roadway delay proportionally among all roadway users.
3. Protect the public investment in transit service.
4. Give an advantage to vehicles that maximize person throughput.

In addition to AASHTO's guidance, the report also recommends including the following community factors in making decisions:

- Improvements to the community's mobility options;
- Support for the community's long-term economic development vision;
- Support for community goals to promote greater use of non-automobile modes;
- Environmental impacts.

Strategy Selection

The report includes a Strategy Selection Matrix, intended to help practitioners identify specific transit supportive approaches to apply. The matrix reviews key costs, benefits, and related issues associated with various transit supportive strategies identified in the report. Three treatments – bus lane, red treatment, and TSP – are included in the table below, adapted from the original report. However, the full matrix can be viewed in TCRP 183 on page 45, Table 5.

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[85] *TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies*. Transportation Research Board (TRB), 2016. https://www.nap.edu/download/21929

Strategy	Bus lane, general	Red pavement	Signal priority
Typical Application	BRT, high bus volumes	Bus lanes	Signals
Traffic Volumes	V/C between .5 and 1.0	Any	V/C between .5 and 1.0
Bus Volume	Approx. 10-100 busses per hour	Any	<10 to 30 buses per hour
Bus Speed	Typical bus delay benefit, on a per-site or per block basis, between 15s and 60s	No effect	Typical bus delay benefit, on a per site or per block basis, of no effect to 15s (TCRP 183 Benefits section of TCRP 183 provides quantitative data on calculating this)
Bus Reliability	Relative impact on bus travel time variability is positive	No effect	Larger impact relative to other strategies
Auto Speed	Relative impact on automobile travel times - worsens automobile travel times to no effect.	No effect	Worsens travel time to improve travel time
Planning Costs	High planning costs	High planning costs	Moderate to high planning costs
Capital Costs	<$10,000 to >$100,000 capital costs	>$100,000 capital costs.	>$100,000 capital costs
Other Issues	Enforcement, part-time or conditional operation feasible	Support strategy that allows other strategies to work better, FHWA experimentation request needed	Part-time or conditional operation feasible, changes to traffic laws or design standards, signal controller capability

Transit Lanes Suitability

Although the guide does not propose specific "warrants," it does provide specific guidance around where transit lanes are suitable. The following three situations are proposed as being suitable for transit lanes:

1. On urban streets with relatively high bus and general traffic volumes, where many buses and their passengers are subject to delay;
2. In corridors with BRT or other premium bus service, where maximizing bus speeds and reliability is a priority; and
3. On shorter stretches of roadway, allowing buses to bypass a bottleneck or to move to the front of a queue (Kittelson & Associates et al. 2013).

Transit Lane Turning and Shared Uses

The report notes that although time savings from bus lanes are reduced by half when right turns by all vehicles are allowed in CBD areas, in some cases excluding right lanes is not feasible. In cases where right turns are allowed, the guidebook provides several strategies, including creating a right turn lane to the right of the bus lane, access management (in suburban areas), and ending the bus lane and instead implementing a signal modification at intersections. In cases where bus volumes are lower and policy support is not as strong, the guidebook recommends allowing other uses in bus lanes to build support.

Use of Red Surface Treatments

The report includes the use of red colored pavement – either for segments or the entire lane – as a transit-supportive strategy that reduces the number of violations of lane restrictions. The color is intended to supplement traditional signs and pavement markings, not replace them. The report indicates the use of red coloring in situations where the lane is "reserved exclusively or primarily for buses."

As of 2016, MUTCD did not permit the use of red treatments to designate transit lanes. However, TCRP 183 anticipates this to change in the next update to MUTCD. Further, the report notes that permission for red treatments have been applied – enabled with a FHWA Interim Approval – in New York City, San Francisco, Chicago, and Seattle. TCRP 183 Appendix D contains a "Request to Experiment Template," provides a model letter to request permission to apply red treatments to transit lanes.

Design Considerations

For bus lane width guidance, the guidebook references the AASHTO *Guide for Geometric Design of Transit Facilities on Highways and Streets* (2014), which allows bus lane widths to a minimum of 11 ft. In cases where bus lanes are shared with bicycles, the guidebook recommends 14.5 ft. to 16 ft. widths.

Duration of Restrictions

Transit priority lanes can be operated on a full-time or part time-basis. While full-time transit priority lanes provide the greatest benefit to transit performance and reliability, part-time lanes allow for other uses to take advantage of the right-of-way during off-peak hours. Uses permitted during off-peak hours can include parking, deliveries, and mixed-traffic operations. In cases where part-time operations are implemented, off-peak enforcement is required to minimize violations and ensure the right-of-way is available for transit use during peak hours.

Shared Uses and Right Turns

Transit priority lanes can be designated exclusively for transit vehicles, or other uses can be allowed to share the lane. Depending on the environment, right-turning vehicles, bicycles, or taxes may be allowed to share the right-of-way. Allowing other uses to share a transit lane can reduce the performance benefits realized by transit vehicles. For example, allowing right-turning vehicles has been shown to reduce transit speed improvements by nearly 50 percent. Shared uses should be considered in environments where transit volumes are low or where allowing other uses may help support implementation of the lanes. In cases where other uses are permitted, companion strategies should be considered to mitigate the impact. If right-turning vehicles can use the lane, strategies such as access management and queue jumps at intersections can reduce some of the performance impacts on transit.

Transit Signal Priority (TSP) Considerations

The guidebook notes that TSP generally reduces traffic delays on the intersection approach used by buses, thereby increasing bus speeds and improving travel time variability. The following general characteristics are provided to identify situations where TSP is suitable:

- Peak intersection v/c ratio between 0.6 and 0.9
- High transit ridership (existing or future)
- Generally, at least four buses per hour, but not too many buses to modify every cycle
- Intersections with far-side bus stops or bus stops that can be moved to the far side

Due to the cost in planning and implementation and the variances in outcomes of TSP installations, the guidebook recommends evaluating corridor characteristics, signal capabilities, bus stop locations, and signal spacing prior to the installation. In general, while the guidebook refers to *NCHRP Report 812: Signal Timing Manual* for further reference on TSP.

While most studies evaluating installations and simulations have found TSP to result in travel time savings for transit vehicles, the report notes that travel time savings are not always achieved. The report includes the followings reasons for why in some applications TSP may not achieve the desired benefit:

- Peak intersection v/c ratio between 0.6 and 0.9
- High Restrictions are too restrictive or not programmed correctly
- Bus schedules are not updated to reflect potential time savings, resulting in fewer late buses
- Incorrect locations selected for TSP
- Traffic congestion too high for buses to be able to take advantage of early or extended green.
- Too little traffic congestion to result in travel time savings
- Signal spacing too dense to result in overall time savings

TCRP REPORT 183: A GUIDEBOOK ON TRANSIT-SUPPORTIVE ROADWAY STRATEGIES		
Topic Area	**Indicator**	**Findings**
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	
	Transit Mode Share	
	Traffic Volume	V/C ratio between 0.5 to 1.0 for bus lanes, generally
	Non-Motorized Users	Shared lane with bicycles recommended where number of buses in lane is low or in constrained rights-of-way
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	Bus lanes usually have a positive effect on transit reliability. Magnitude of benefit varies.
	Transit Service Frequency	Observed bus volumes/recommendations range from 10 buses per hour to 100 buses per hour. Contexts vary.
	Transit Signal Priority	Typically strong benefit to transit and reliability, but modest impact on typical bus speeds. Apply in corridors with V/C ratios between 0.5 and 1.0, as higher V/C ratios reflect congestion levels that overwhelm TSP benefits. Suitable in corridors with fewer than 10 buses per hour. Can degrade auto travel time reliability.
	Person/Vehicle Delay	Transit lanes and TSP can degrade auto travel times and reliability but often have a negligible impact.
	Average Travel Speeds	Transit lanes improve bus travel times from 15 to 60 seconds per block, typically.
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	
	Accessibility	
	Facility Functional/Access Class	Bus travel time savings limited by right-turning vehicles in the bus lane. Driveway consolidations and other access management may optimize bus lane benefits.
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	
	Lane Width	11’ minimum; 12’-13’ recommended; 16’ for shared lane
	Intersection Design	
	Separation of Traffic	(See “non-motorized users” above)
Other	Safety	Facility and service design (speed limits, lane width, stop spacing, shared uses, etc.) are critical for safety.
	Enforcement	Red surface treatments reduce violations; violations undermine transit travel time benefits; full-time lanes are easier to enforce than part time lanes.
	Maintenance	
	Cost	Bus lanes can have high planning costs due to coordination and public engagement; capital costs roughly $10,000 to $100,000 per block.
	Project length	

BUS PRIORITY TREATMENT GUIDELINES

Metropolitan Washington Council of Governments (MWCOG), 2011[86]

Report Summary

This report identifies a mixture of potential treatments for implementing previously designated transit priority corridors. Potential treatments explored in the guidebook include exclusive bus lanes, bus stop location, bus bulbs, queue jumpers, transit signal priority (TSP), bus stop design, and bus shelters. The guidebook recommends an approach that maximizes person throughput instead of focusing solely on LOS and volume-to-capacity (v/c) ratios.

Bus Lane Identification Criteria and Considerations

This document presents guidelines for the applicability of bus lanes based on the automobile Level of Service (LOS). For roadways operating at LOS A, B, or C, exclusive transit lanes are likely to be a feasible and appropriate solution. At LOS D, exclusive lanes may be an option, but restricted use lanes that have fewer impacts on adjacent traffic should also be considered. At LOS E or worse, traffic impacts from implementing an exclusive lane undermine potential benefits and are usually not appropriate.

The document also offers coarse guidelines for identifying bus lane needs based on several indicators:

- **Peak hour bus volumes**: 30-40
- **Passenger volumes**: 1,200 or higher per hour
- **Ratio of bus passengers to automobile passengers**: At least 1:1, looking at either existing and/or projected ridership

Design Considerations

The report notes that in some situations, only portions of a corridor need a designated bus lane for benefits to be achieved. Regarding transit lane width, the report notes that optimal width is between 12-13 feet. However, 11-12 feet is also considered acceptable. Paint and signage are important in the design and serve as low-cost forms of enforcement. However, the report notes that colored lanes are only appropriate in situations where restrictions on lane usage are in place at all times.

Enforcement

The report raises several considerations around enforcement, noting that designating an entity responsible for enforcement can be difficult, especially in multi-jurisdictional cases. The report recommends that during all project phases -- from planning to operations -- it is important to include all entities involved in enforcement activates and inform them of the costs and benefits.

Transit Signal Priority (TSP) Considerations and Applicability

In general, the report notes that TSP benefits transit at little cost to traffic. It provides several indicators that determine where TSP can be effective and should be applied. These indicators include:

- Bus delays are present due to heavy traffic congestion
- Most effective at intersections with LOS D or E
- V/C between 0.8 and 1.0 (TSP on corridors above v/c of 1.0 has been shown to be ineffective)

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[86] Bus Priority Treatment Guidelines Metropolitan Washington Council of Governments (MWCOG), 2011. https://nacto.org/docs/usdg/bus_priority_treatment_guidelines_national_capital_region_trans_planning_board.pdf

BUS PRIORITY TREATMENT GUIDELINES (MWCOG)

Topic Area	Indicator	Findings
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	
	Transit Mode Share	Bus lanes warranted when peak hour bus volumes are between 30-40 buses per hour and passenger volumes are 1,200 or higher per hour in a corridor. Alternatively, bus lanes warranted when buses carry as many people as automobiles in adjacent lanes.
	Traffic Volume	
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	
	Transit Signal Priority	Most effective at LOS D-E conditions with V/C ratios between 0.80 and 1.00. Limited benefit at LOS A-C. V/C > 1.00 may present long vehicle queues that limit the effectiveness of TSP.
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	Maryland Complete Streets policies apply to bus lanes, loosening lane restrictions and allowing more users.
	Parking/Curb space	Parking should be removed form a street where an exclusive curbside bus lane is being considered under the following conditions: traffic volumes are between 500-600 vehicles per lane per hour, LOS for the street is E or F, and travel speeds fall below 20mph.
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	Bus lanes can be reversible and restricted to peak travel direction. This prioritizes buses in the peak travel direction and limits impacts on highway capacity.
	Lane Width	11′ minimum; 12′-13′ recommended.
	Intersection Design	
	Separation of Traffic	Restrictions most appropriate at LOS A-C, restricted or exclusive lanes at LOS D, exclusive lanes not feasible at LOS E or worse. Give consideration to delivery/municipal vehicles.
Other	Safety	Streets where parking has been removed to accommodate bus lanes have shown a reduction in collisions (15%-20%).
	Enforcement	Include enforcement partners early in the process. Passive enforcement lower cost than active enforcement (policing or video surveillance). Red surface treatments reduce violations.
	Maintenance	
	Cost	
	Project length	Bus lanes need not span the entire length of a corridor to confer benefits.

SURFACE TRANSPORTATION OPTIMIZATION AND BUS PRIORITY MEASURES: THE CITY OF BOSTON CONTEXT

A Better City, 2010[87]

Report Summary

The purpose of this report is to develop recommendations around the implementation of bus operations optimization measures in Boston, MA. Although the report's primary objective is not to perform an analysis and identify specific corridors for improvements, the report includes a literature review component that identifies best practices for a variety of bus treatments. Since this review has a more specific scope than the document, a focus was taken on sections of the report addressing transit way treatments, such as bus exclusive lanes, and transit signal priority (TSP).

Transitway Treatment Considerations

Transit running way treatments are one of the bus optimization measures reviewed in the report. The table below, reproduced based on Exhibit 5 in the report, shows the considerations identified as part of the report's literature review.

Type	Applicability	Potential Benefits	Potential Impacts	Considerations
Exclusive Lanes	High volume streets operating at levels of service A, B, or C	Improved bus schedule reliability, higher bus speeds	Reduction of private vehicle capacity or increased congestion of remaining mixed traffic lanes; elimination of curb parking spaces	Traffic impacts, reduction of parking capacity, turning movements
Restricted Lanes	High volume streets operating at levels of service A, B, or C	Improved bus schedule reliability, slightly higher bus speeds, HOV capacity	Less reduction of private vehicle capacity but risk of bus delays by HOV's; elimination of curb lane parking	Untrained drivers use of lane, signage, enforcement, safety and turning movements.
Unrestricted Lanes	High volume streets operating at levels of service E or F	Designated stop space, potential to provide a bus shelter and paved landing pad	Little to not improvement in bus operations	Unchanged operational environment for buses

Cost Estimates

The report identifies planning level cost estimates for the installation of bus lanes for scenarios where the lane is either existing, new, or is a median transitway. Cost estimates identified in the report are illustrated in the table below, reproduced based on Exhibit 11 (citing year 2003 values) in the report.

Treatment	Capital Cost	Operation and Maintenance
Existing lane converted to bus lane	$50k to $100k per mile	Minimal
Curb or off-set lanes	$2 to $3 million/lane-mile	Under $10k/lane-mile/year
Median transitway	$5 to $10 million/lane-mile	Under $10k/lane-mile/year

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[87] *Surface Transportation Optimization and Bus Priority Measures: The City of Boston Context*. A Better City, 2010. https://www.abettercity.org/docs/Surface%20Transportation%20Optimization%20and%20Bus%20Priority%20Measures%20Final.pdf

Cost Effectiveness

The report offers a cost-effectiveness matrix intended to help frame various transit supportive measures based on its own extensive literature review. The report's findings are illustrated below in a table reproduced from Exhibit 28 in the report. This figure is intended to help frame the various types of bus priority improvements identified in the report in terms of relative costs and effectiveness. Although this matrix was developed with the Boston context in mind, the general concept is translatable to other areas.

		COST		
		Low	**Medium**	**High**
EFFECTIVENESS	**High**	Stop Consolidation	Restricted Bus Lane	Exclusive Bus Lane Proof of Payment (PoP)
	Medium	C2C TSP Stop Placement	Two-Door Boarding	
	Low	Queue Jump	Curb Extension	

Corridor Evaluation Framework

Although the primary purpose of this report is not to identify and rank corridors for transit-supportive treatments/optimizations, the report does use several metrics to evaluate existing transit routes and highlight those that could benefit the most from transit optimizations. These include:

- Lowest average speed per segment (AM, PM, or all day).
- Greatest travel speed reductions identified in model forecast (from 2005 to 2015).

SURFACE TRANSPORTATION OPTIMIZATION AND BUS PRIORITY MEASURES: THE CITY OF BOSTON CONTEXT		
Topic Area	**Indicator**	**Findings**
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	An MBTA study evaluated the increase in ridership by route using the CTPS Travel Demand Model. Study ranked routes anticipated to experience the highest increases in ridership by percent increase.
	Transit Mode Share	
	Traffic Volume	LOS A-C
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	
	Transit Service Frequency	
	Transit Signal Priority	
	Person/Vehicle Delay	
	Average Travel Speeds	Study identified hotspots using average vehicle travel speed by segment. MBTA buses generally experience bus average bus speeds of approximately 11.4 MPH throughout the day (9.6 in AM peak, 8.4 in PM peak). Top 10 hot spots have transit speeds of 3.5 to 4.9 mph.
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	
	Lane Width	
	Intersection Design	
	Separation of Traffic	
Other	Safety	
	Enforcement	
	Maintenance	Existing lane converted to bus lane: Minimal Curb or off-set lanes: Under $10k/lane-mile/year Median transitway: Under $10k/lane-mile/year
	Cost	Existing lane converted to bus lane: $50,000 to $100,000 per mile Curb or off-set lanes: $2 to 3 million/lane-mile Median transitway: $5-10 million/lane-mile
	Project length	

TRANSIT STREET DESIGN GUIDELINES: TRANSIT LANES

National Association of City Transportation Officials (NACTO) [88]

Report Summary

The National Association of City Transportation Official (NACTO) Transit Street Design Guide provides a framework for developing transit corridors. The guidebook offers considerations and recommendations with a focus on complete streets and comprehensive network considerations. Included in this review are guidebook highlights for the most common transit-exclusive and transit priority lane configurations.

Transit Lanes Suitability and Considerations

In general, the guidebook notes that transit lanes are well-suited for streets with high vehicle volumes and/or vehicle congestion in the context of downtown and/or corridor applications. It also states that decisions around implementing a transit lane should focus on the following factors, without being limited by any one factor:

- Transit volume (current and future)
- Transit demand (current and future)
- Potential to reduce total person delay
- Potential to limit increases to average travel time (both short and long-term)

In addition, the following indicators are suggested to identify streets that will realize the greatest benefits from transit lanes: travel time variability, travel time reliability, and boardings along the corridor. The guidebook recommends that Level-of-Service (LOS) analysis should be used only to consider queue lengths and potential network impacts and not for screening streets for applicability.

Transit Lanes Design

Transit lanes can be operated as full-time or part-time, depending on corridor characteristics. The greatest benefits are achieved with continuous lanes. Transit lanes should be designated with markings, signs, and regular enforcement. Red treatments are recommended to increase awareness. Desired transit lane width is 10-20 feet, depending on adjacent lane uses. A bus stop, for example, may only need 9ft, while a shared use lane with bicycles requires more than 14.5 ft.

Enforcement

The guidebook recommends automated enforcement as a preferred alternative to more expensive human enforcement. It also notes that full-time restricted lanes can reduce violations.

Managing Turns and Shared Uses

The guidebook recommends that turn management is necessary to preserve the benefits of transit lanes. Recommendations for managing turns include:

- Prohibitions on turning, which can be vital to preserving and enhancing transit performance.
- Accommodations for turns, including short facilities near intersections, such as right-turn pockets.
- Shared transit lanes with bikes and right turns.
- Dropping transit lanes at intersections.

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[88] *Transit Street Design Guide: Transit Lanes.* National Association of City Transportation Officials (NACTO), 2018. https://nacto.org/publication/transit-street-design-guide/transit-lanes-transitways/transit-lanes/

Transit Signal Priority (TSP)

The guidebook notes that TSP is a powerful tool for reducing transit vehicle delays by modifying traffic signal timing. The publication notes that some of the largest benefits are achieved in situations where TSP is implemented alongside other transit-supportive strategies, such as transit lanes. The guidebook notes that delays can be reduced by around 10 percent. At some specific intersections, transit delay reductions can reach 50 percent.

The guidebook provides characteristics of corridors where TSP should be included. General guidelines include situations where:

- Where transit delays are experienced are due to signals, with or without congestion.
- Intersections where the transit vehicle can reach the signal to take advantage of the extended green, in either mixed traffic or a dedicated lane or queue jump.
- Corridors with long signal cycle timings and/or large distances between signals
- Where turning transit routes can benefit from a special turn phase
- Corridors with moderate to long headways
- Intersections where a bus stop is, or can be, located on the far side

One challenge with TSP is the high level of coordination that is required between agencies for a successful implementation. Coordination is needed to make sure the technology on-board transit vehicles works with signal systems and schedules. In some cases, long-term agreements between the involved agencies is needed to ensure the system operates as intended.

TRANSIT STREET DESIGN GUIDELINES: TRANSIT LANES (NACTO)		
Topic Area	**Indicator**	**Findings**
Demand *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit Ridership	Bus lanes implementation should be informed by multiple factors, with emphasis on transit volume, including future demand, and reduction in total person delay or limited increases to average travel time.
	Transit Mode Share	
	Traffic Volume	Streets with high traffic volume and congestion are good candidates for dedicated lanes, which organize traffic flow and improve on-time performance and transit efficiency. Auto LOS is not an acceptable planning factor when viewed in isolation. Its use should be limited to understanding queue lengths and other changes with potential network impacts.
	Non-Motorized Users	
	Person Throughput	
Operations *(Existing v. Forecast v. Targets, Peak v. Off-Peak v. Daily)*	Transit On-Time Performance	
	Transit Reliability (Route Travel Time)	Transit travel time variability and reliability over the day are a good indicator of the potential benefits of transit lanes, especially if boardings are consistent throughout.
	Transit Service Frequency	
	Transit Signal Priority	
	Person/Vehicle Delay	
	Average Travel Speeds	
Contexts *(Nearby uses, disadvantaged population, connectivity, freight routes, emergency routes)*	Adjacent Land Uses	
	Context Classification/ Complete Streets	
	Parking/Curb space	Transit lanes are broadly applicable on downtown and corridor streets where transit is delayed by congestion and curbside activities, such as parking/standing.
	Accessibility	
	Facility Functional/Access Class	
Design *(Available ROW, shared modes/ movements)*	Number of Lanes	
	Lane Width	
	Intersection Design	
	Separation of Traffic	
Other	Safety	
	Enforcement	Markings, signage, and enforcement maintain the integrity of transit lanes. Automated electronic enforcement, including license-plate readers or video, is preferable to labor-intensive patrols.
	Maintenance	
	Cost	
	Project length	

Bus Lane Enforcement Study

Metropolitan Washington Council of Governments (MWCOG), 2017[89]

Report Summary

The purpose of this study is to identify strategies that will lead to better compliance and enforcement of bus lane regulations. The study is based on a best practice reviews at a local and national scale and includes a benefit cost analysis. An implementation plan was then developed from these findings.

Stakeholder Coordination

The report emphasizes a need for cooperation during the entire implementation process between local and state agencies as well as between officials in traffic engineering, operations, and transit service planning.

Enforcement

The study identifies both police and automated enforcement. Studies show that a perception of low enforcement levels for transit lanes leads to higher violation rates, indicating some level of police enforcement is needed. However, this comes at a cost. The study identifies automated enforcement as a more cost-effective option, however it notes that many times enabling legislation is needed.

Legislation

The study indicates that legislation is typically necessary to enable and implement a variety of enforcement-related activities, including reporting requirements, enforcement hours, fine amounts, etc.

FIGURE 2 KEY ELEMENTS TO EFFECTIVE BUS LANE IMPLEMENTATION

Education

The study notes that education is a crucial component. The study recommends utilizing messaging during all phases of a project that is tailored to specific audiences that are relevant to the project. Additionally, it is recommended that education be provided directly to transit operators.

Monitoring

After a bus lane is implemented it is recommended that performance measures be identified to evaluate the lane. Metrics recommended include compliance and violation rates.

Benefit Cost Analysis

The report provides a high-level look at benefits and costs. Table 5 provides benefit-cost ratios for various transit lane implementation scenarios. This table is helpful in evaluating the cost-effectiveness of various treatment options. Table 3 and 4 provide cost units develops for the benefit-cost analysis.

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[89] *Bus Lane Enforcement Study*. Metropolitan Washington Council of Governments (MWCOG), 2017. https://www.mwcog.org/assets/1/28/10062017_-_Item_12_-_DO_NOT_PRINT_-_Bus_Lane_Enforcement_Study_Final_Report.pdf

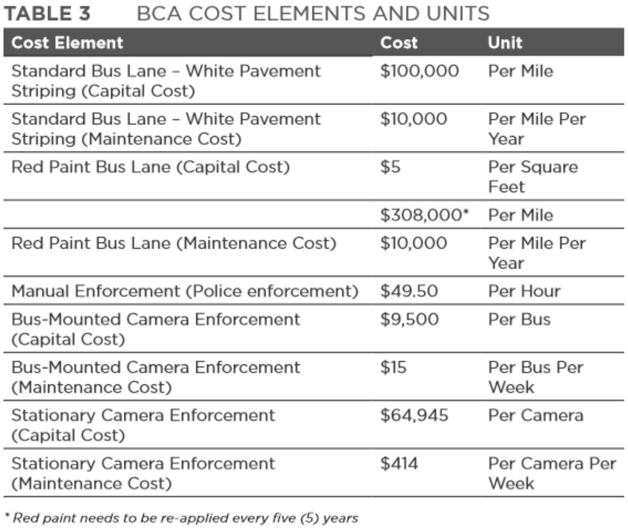

TABLE 3 BCA COST ELEMENTS AND UNITS

Cost Element	Cost	Unit
Standard Bus Lane – White Pavement Striping (Capital Cost)	$100,000	Per Mile
Standard Bus Lane – White Pavement Striping (Maintenance Cost)	$10,000	Per Mile Per Year
Red Paint Bus Lane (Capital Cost)	$5	Per Square Feet
	$308,000*	Per Mile
Red Paint Bus Lane (Maintenance Cost)	$10,000	Per Mile Per Year
Manual Enforcement (Police enforcement)	$49.50	Per Hour
Bus-Mounted Camera Enforcement (Capital Cost)	$9,500	Per Bus
Bus-Mounted Camera Enforcement (Maintenance Cost)	$15	Per Bus Per Week
Stationary Camera Enforcement (Capital Cost)	$64,945	Per Camera
Stationary Camera Enforcement (Maintenance Cost)	$414	Per Camera Per Week

** Red paint needs to be re-applied every five (5) years*

TABLE 4 STRATEGIES AND ASSOCIATED ESTIMATED COSTS

Implementation Strategies[1]	Bus Lane Capital Cost ($)	Bus Lane Maintenance Cost ($/year)	Enforcement Capital Cost ($)	Enforcement Maintenance Cost ($/year)
Standard Lane Treatment - No Enforcement	$100,000	$10,000	-	-
Standard Lane Treatment - Low Manual Enforcement	$100,000	$10,000	-	$12,375
Standard Lane Treatment - Moderate Manual Enforcement	$100,000	$10,000	-	$49,500
Standard Lane Treatment - Maximum Manual Enforcement	$100,000	$10,000	-	$99,000
Standard Lane Treatment - Bus-Mounted Automated Enforcement	$100,000	$10,000	$142,500	$11,250
Standard Lane Treatment - Stationary Automated Enforcement[2]	$100,000	$10,000	$129,891	$41,382
Red Paint Bus Lanes[3] - No Enforcement	$308,000	$10,000	-	
Red Paint Bus Lanes[3] - Low Manual Enforcement	$308,000	$10,000	-	$12,375
Red Paint Bus Lanes[3] - Moderate Manual Enforcement	$308,000	$10,000	-	$49,500
Red Paint Bus Lanes[3] - Maximum Manual Enforcement	$308,000	$10,000	-	$99,000
Red Paint Bus Lanes[3] - Bus-Mounted Automated Enforcement	$308,000	$10,000	$142,500	$11,250
Red Paint Bus Lanes[3] - Stationary Automated Enforcement[2]	$308,000	$10,000	$129,891	$41,382

[1] Assumes one (1) year of implementation and operation along a one (1) mile corridor running with a frequency of fifteen (15) buses per hour
[2] Assumes two (2) enforcement locations per mile, and two (2) cameras per enforcement location
[3] Red paint needs to be re-applied every five (5) years

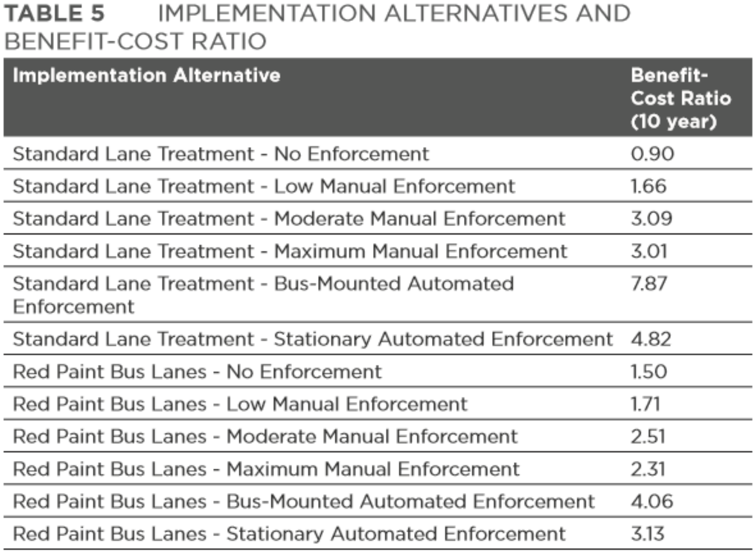

TABLE 5 IMPLEMENTATION ALTERNATIVES AND BENEFIT-COST RATIO

Implementation Alternative	Benefit-Cost Ratio (10 year)
Standard Lane Treatment - No Enforcement	0.90
Standard Lane Treatment - Low Manual Enforcement	1.66
Standard Lane Treatment - Moderate Manual Enforcement	3.09
Standard Lane Treatment - Maximum Manual Enforcement	3.01
Standard Lane Treatment - Bus-Mounted Automated Enforcement	7.87
Standard Lane Treatment - Stationary Automated Enforcement	4.82
Red Paint Bus Lanes - No Enforcement	1.50
Red Paint Bus Lanes - Low Manual Enforcement	1.71
Red Paint Bus Lanes - Moderate Manual Enforcement	2.51
Red Paint Bus Lanes - Maximum Manual Enforcement	2.31
Red Paint Bus Lanes - Bus-Mounted Automated Enforcement	4.06
Red Paint Bus Lanes - Stationary Automated Enforcement	3.13

BUS LANE TREATMENT EVALUATION

New York City Department of Transportation (NYCDOT), 2012[90]

Report Summary

This publication documents research that utilized both long-term field observations and lab evaluations to identify the durability and skid resistance of surface treatments for red bus lanes in New York City. The report provides recommendations based on research findings on red surface treatments.

Research Findings and Recommendations

Based on lab and field observations, the study drew five overarching conclusions/recommendations:

- Products based on Portland cement are not effective on asphalt or cement surfaces.
- Products with a primary purpose of providing anti-skid surfaces accumulate dirt and degree.
- On asphalt surfaces, epoxy street paint products are durable.
- Asphalt concrete-based micro surfaces show potential.
- Surface pre-treatment, when done aggressively, improves epoxy street paint performance.

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[90] *Red Bus Lane Treatment Evaluation*. New York City Department of Transportation (NYCDOT), 2012. https://nacto.org/docs/usdg/red_bus_lane_evaluation_carry.pdf

REPORT ON THE EFFICACY OF RED BUS LANES AS A TRAFFIC CONTROL DEVICE

New York City Department of Transportation (NYCDOT), 2011[91]

Report Summary

This paper reports New York City Department of Transportation (NYCDOT) and Metropolitan Transportation Authority (MTA) findings around the effectiveness of using red colored pavement to designate exclusive bus lanes. After reviewing findings, the paper concludes that "red treatment is an effective and safe traffic control device suitable for inclusion in the Manual on Uniform Traffic Control Devices (MUTCD)."

Research Findings and Recommendations

The research identified several key findings and recommendations. These include:

- Designating bus only lanes with red paint reduces unauthorized driving and parking in bus lanes.
- Curb bus lanes that received a red treatment saw illegal standing reduced by 1/3
- Designating curbside bus lanes with red treatment did not reduce parking occupancy rates during periods when parking is allowed.

Designating bus lanes with red treatment did not significantly alter the portion of drivers who used the bus lane versus mixed lane for making right turns.

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[91] *Report on the Efficacy of Red Bus Lanes as A Traffic Control Device*. New York City Department of Transportation (NYCDOT), 2011. http://stb-wp.s3.amazonaws.com/wp-content/uploads/2014/10/Summary-Red-Lane-Efficacy-Report-to-FHWA-v3.pdf

PRIMER ON TRANSIT LANE CONSPICUITY THROUGH SURFACE TREATMENT

Transportation Association of Canada, 2010[92]

Report Summary

This report provides specific guidance on the benefits, cost-effectiveness, enforcement, and installation of red surface treatments to designate transit priority lanes. The findings, which are intended to inform and guide transportation professionals in Canada, are drawn from international research, including studies in the United States.

Red Surface Treatment Recommendations

The report notes that red surface treatments are the most cost-effective method for increasing motorist compliance is increasing the visibility of transit only lanes. It notes that studies in the United States, Canada, and internationally have found that red paint significantly decreases or eliminates transit lane violations. Several pilot projects in Canada have identified 50-100 percent reductions in violations

Red lanes reduce the need for police enforcement, but they do not eliminate it. Red surfaces should only be used to designate full-time, 24/7 transit lanes. Allowing cars to utilize red-colored lanes during parts of the day reduces their effectiveness.

Project Length and Duration

The project notes that it is not always necessary to use red surface the entire project length to designate transit only lanes. The UK, Australia, and New Zealand have found it to be sufficient to only use red surface to designate the beginning, middle sections, and end of transit lanes.

One strategy outlined in the report is limiting red surfacing to segments of a transit lane can be an effective strategy to reduce project costs. Additionally, red surface treatments can be used as a temporary measure for approximately 6-24 months when a new transit lane is introduced to help raise awareness. After this time frame, traditional signage may be sufficient in some circumstances.

Material Recommendations

The report provides some basic guidance into the use of red paint versus red colored materials, noting that:

- Red paint is less expensive and lasts approximately 3 to 5 years.
- Colored materials that require a new top layer are more expensive but last longer.

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[92] *Primer on Transit Lane Conspicuity Through Surface Treatment*. Transportation Association of Canada, 2010. https://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/primer-transit-conspicuity2010.pdf

Developing Dedicated Bus Lanes Screening Criteria in Baltimore, MD

Transportation Research Record, 2018[93]

Report Summary

This report reviews how Maryland Transit Administration (MTA), working with the City of Baltimore, developed performance measures and screening criteria for the identification of candidate bus lane corridors in Baltimore, MD.

Literature Review Findings

This study included a literature review and case studies. Although the report notes, "there is no clear consensus on specific performance measures that should be used for selecting streets," the literature review and case studies did identify several key performance measure themes, including:

- Frequency of service;
- Person throughput;
- Average speed and reliability;
- Automobile level of service (LOS).

The study also notes that "person throughput was perhaps the most useful performance measure for assessing how streets are currently being utilized, moving the conversation toward equitable transportation solutions instead of transportation by private vehicle."

Identifying Candidate Streets

In order to identify candidates for dedicated bus lanes, the Baltimore team developed a set of performance measures that were derived in part from the literature review findings. A tiered analysis was then used, beginning with the following general set of criteria to select the first 25 streets for consideration:

- relatively high frequency and ridership
- some level of travel time delay
- reliability issues

Preliminary Criteria

After the team identified a set of candidate corridors, a preliminary screening was developed. The preliminary screening criteria was comprised of the following factors:

- Level of bus service planned on a corridor
- Person throughput by mode
- Spatial feasibility

Detailed Screening

After the preliminary screening was conducted, a detailed analysis was then conducted on the remaining streets. The measures used for the full evaluation are documented in tables 4-6, from the report, reproduced below.

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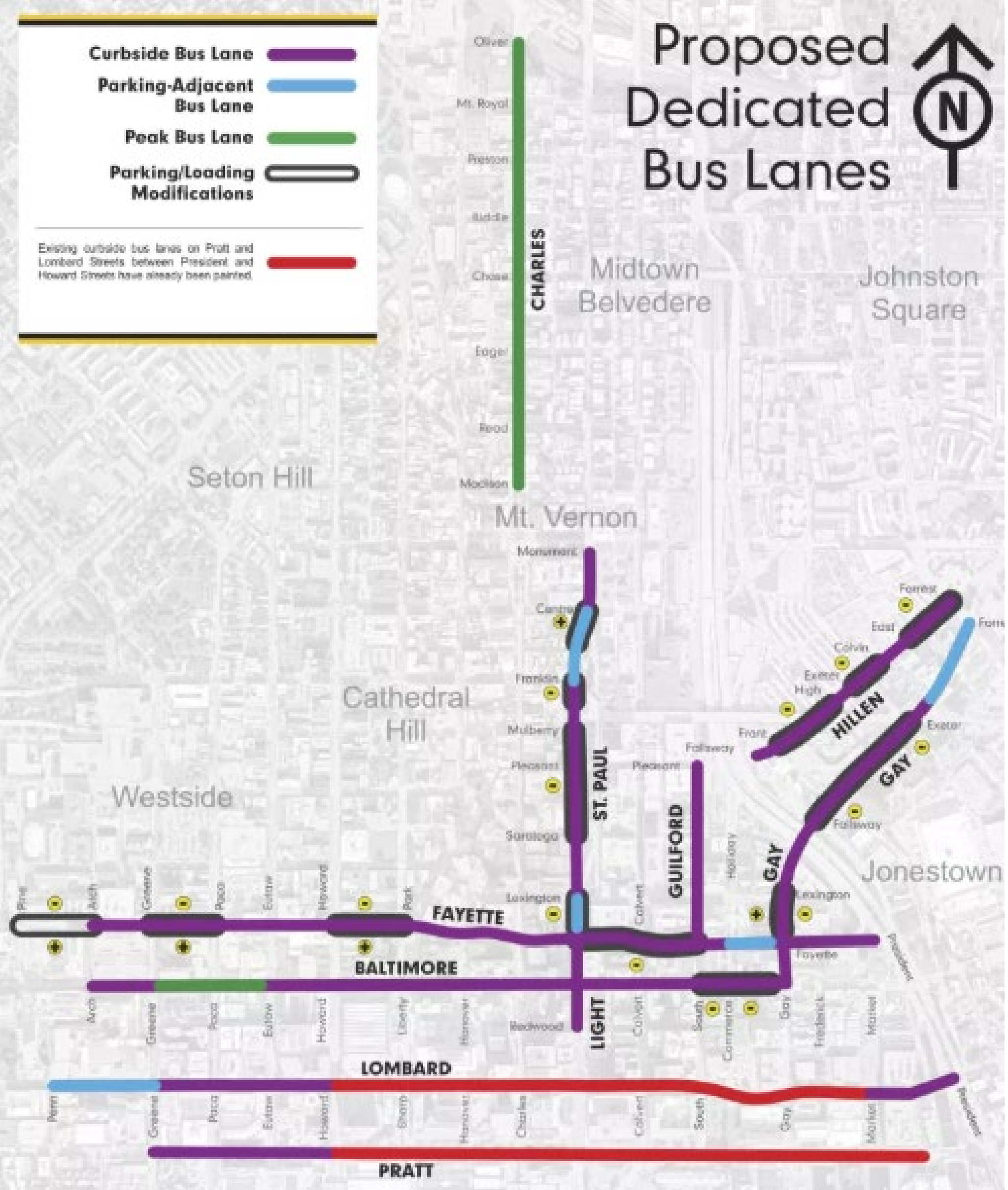
[93] *Developing Dedicated Bus Lane Screening Criteria in Baltimore, Maryland.* Transportation Research Record, 2018. https://journals.sagepub.com/doi/abs/10.1177/0361198118797827

Performance Measures	Auto	Transit
Person Throughput	Bus lane should carry approx. 80% to 120% of the adjacent auto lane. The flexibility/range allows for consideration of exclusive bus lanes, business access and transit lanes, peak period bus lanes, and use of consecutive turn lanes and on-street parking conversion.	
Person Delay	Change in person delay (passengers/riders/operators of autos and buses) with conversion to bus lane	
Volume (peak hour, peak dir.)/ Frequency	Peak hour: >1000 vehs requires more than 1 auto lane; Daily: >10,000 vehs requires more than 1 auto lane	Curb lane: >= 24 buses (1 bus every 2.5 mins); Offset lane (i.e., adjacent to parking): >= 18 buses (1 bus every 3.3 mins)
Passengers per hour	Not applicable (1.15 passengers per vehicle assumed systemwide per Baltimore Metropolitan Council)	Curb lane (CBD): 2,000 – 3,000; Curb (normal flow): 1,200 – 1,600; Offset lane (i.e., adjacent to parking): >800 (all expressed as peak hour)
Travel time	Projected impacts to be assessed on case-by-case basis, balancing need to move the greatest number of people	
Average speed	> 10 mph below speed limit: bus lane detrimental to corridor mobility; 0 – 10 mph below speed limit: bus lane may have limited mobility impacts; Additional case-by-case considerations given to intersection impacts	< 8 mph: substantial benefits to bus lane; 8 – 12 mph: potential benefits to bus lane; > 12 mph: limited benefits to bus lane; Additional case-by-case considerations given to intersection impacts and potential for transit preferential treatments (e.g., transit signal priority, queue jumps, etc.).
Level of service (LOS)/ delay and v/c	Expected change in LOS/delay and v/c (LOS/delay may be appropriate at LOS "E" [55-80 seconds of average vehicle control delay] if benefits to bus travel are substantial); v/c < 1.0	Expected change in delay
Parking and loading/ unloading impacts	Case-by-case basis to determine potential impacts; likely only applicable for curbside bus lanes, but consideration will also be given to any potential parking and loading/unloading impacts.	
Population near routes	NA	% relevant population accessed within 5-min walk of corridor, bus routes on corridor, or both.
Transit-dependent population near routes	NA	
Access to jobs	NA	# of jobs accessed by bus routes on corridor
Connectivity/transfers	NA	# of direct connections to high-capacity transit (i.e., Metro, light rail, CityLink).
Emergency routes	Yes/No	
Freight routes	Yes/No	
Lane width	10-12 ft: bus lane appropriate; 12-14 ft: consider painted buffer or consider bus/bike lane; >14 ft: consider separate adjacent bike(green) and bus (red) lane.	
Right turns at intersections	< 100 right turns per hour: motorists can use bus lane > 100 right turn lanes per hour: exclusive alternative should be considered (i.e., bus bypass lane, queue jump)	NA

Full Analysis and Recommendations

After the detailed screening was complete, the number of candidate streets was reduced to 10. The team then conducted a full analysis of the remaining 10 candidates. The goal of the full analysis was to identify the impact that adding bus lanes would have on parking and traffic operations. In order to identify the potential impact, the full analysis included a traffic operations analysis, including Synchro models, as well as evaluations of delay on automobile traffic, LOS, and volume-to-capacity metrics. The final output of this process was recommendations for dedicated bus lanes, illustrated below in a map provided in the report.



A map of bus-only lanes in downtown Baltimore (Source: Streets Blog USA)

HART TRANSIT CORRIDOR EVALUATION AND PRIORITIZATION

Detail Review from TCRP Synthesis 83, 2010[94]

Report Summary

Included in TCRP Synthesis 83 is a summary of a 2007 effort in Tampa, FL, to develop a scoring and ranking method to prioritize transit corridor enhancements for the Hillsborough Area Regional Transit Authority (HART) service area.

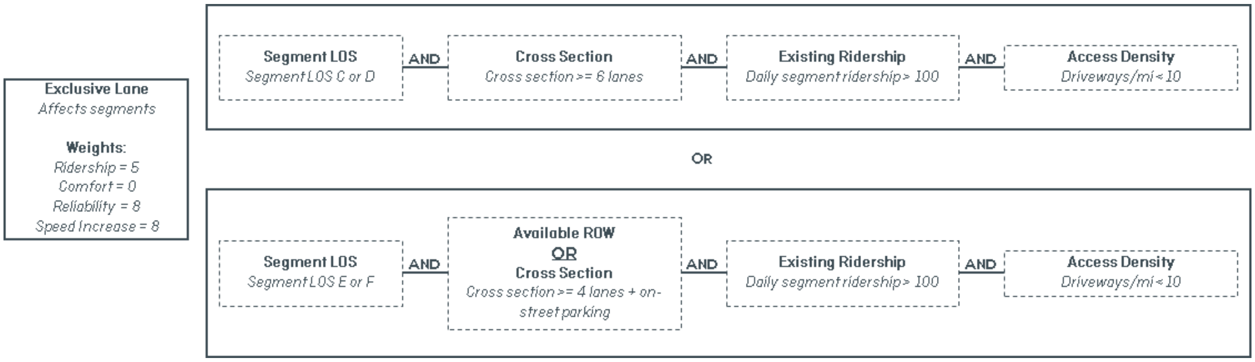
Evaluation Criteria

The study developed a method to evaluate bus treatments that followed three steps:

1. For each location (i.e., corridor segment, intersection, or bus stop), evaluate the factors described in Figure 54.) [*Note: the portion of this figure pertaining to exclusive transit lanes has been re-created below.]*
2. If all of the thresholds are met for a potential improvement at a given location, assign the weights for that potential improvement to the corridor for four different factors—increasing ridership, increasing travel speed (or decreasing delay), increasing passenger comfort, and increasing service reliability).
3. Sum the weights for each location in the corridor for use in corridor prioritization. The weights identified were based on a scale of 0 to 10, where 0 means that it would have no positive impact and 10 means it would have a significant positive impact.

Figure 54 of the synthesis report lists the factors used in step 1 of this process. The portions of this figure pertaining to exclusive transit lanes have been re-created below. Weights were assigned with values ranging from 0-10, with 10 indicating the highest level of positive impact. Total scores were normalized to adjust for varying lengths and densities of intersections and stops.

The authors of the synthesis report note that HART's application of the tool was "a technically sound, flexible, and objective evaluation methodology for prioritizing transit improvements and can serve as the foundation for subsequent policy discussions and decision-making." TCRP 83 suggests this approach "can be applied to the planning level evaluation and prioritization of corridors in any community."



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[94] *TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic*. Transportation Research Board (TRB), 2010. https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf

BUS LANES IN DOWNTOWN MIAMI

Miami-Dade TPO, 2015[95]

Report Summary

This report documents the development and application of a framework to identify bus corridors for potential transit treatments in Miami, FL. The study considers a variety of options for improving transit service, including transit way treatments, TSP, queue jumps, and stop consolidation.

Corridor Evaluation Framework

The study evaluates and maps existing corridors based on several factors, including bus volumes, turning movements, bus speeds, AADT, LOS, and street parking. A "hot spot" analyst was then conducted, which evaluated the bus network segments based on three variables:

- Number of daily bus trips by direction by segment;
- Number of daily boardings by direction by segment;
- Average peak period speed by direction by segment.

Each variable was assigned a score of 1-3. These scores were summed in order to identify the final "hot spot" corridors.

Estimating Costs

The study provides cost estimates for transit lanes. A cost of $200,000 per mile is used for this study in estimating the cost of converting an existing lane to a bus priority lane. Included in the cost estimate is adding appropriate signage and pavement markings.

Estimating Benefits

The study utilizes the *Transit Capacity and Quality of Service Manual, 3rd Edition*, to the estimate time savings benefits from the proposed transit lanes. Included in this summary is a reproduction of Table 4-2 from the report. The table shows bus travel times, in minutes per mile, based on different bus treatments and conditions. The study estimated time savings by calculating the difference (in minutes per mile) between two treatments. The study utilized the 1 minute per mile time savings achieved by a bus operating in a CBD bus lane with right turn delays versus a bus in a CBD mixed traffic lane.

Condition	Bus Lane	Bus Lane, No Right Turns	Bus Lane with Right Turn Delays	Bus Lanes Blocked by Traffic	Mixed Traffic Flow
CENTRAL BUSINESS DISTRICT					
Typical		1.2	2.0	2.5 – 3.0	3.0
Signals set for buses		0.6	1.4		
Signals more frequent than bus stops		1.5 – 2.0	2.5 – 3.0	3.0 – 3.5	3.5 – 4.0
ARTERIAL ROADWAYS OUTSIDE THE CBD					
Typical	0.7				1.0
Range	0.5 – 1.0				0.7 – 1.5

Source: TCRP Research Results Digest 38 (37)
Note: Traffic delays reflect peak conditions

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[95] *Bus Lanes in Downtown Miami: Final Report.* Miami Dade TPO, 2015. http://miamidadetpo.org/library/studies/downtown-miami-bus-lanes-final-report-2015-12.pdf

ADDITIONAL READING

The table below provides a run-down of all the studies and publications considered for this literature review. The selections summarized above provide insight into a variety of key issues in RED lanes planning and implementation. Other reports provide similar valuable insight, but not all could be summarized adequately. Brief synopses are provided for each report to guide interested readers in additional potential RED lanes-related resources.

Document Name	Published By	Description	Document Focus
Mount Auburn Street Bus Priority Pilot: Questions & Answers https://www.cambridgema.gov/CDD/Projects/Transportation/~/media/57A6461830A84736802722B645AE9790.ashx	Cambridge Watertown BRT	Fact sheet about rollout of bus priority lanes in Cambridge, MA that allow bicycles and red turns for cars.	Case Studies
Developing Dedicated Bus Lane Screening Criteria in Baltimore, MD https://journals.sagepub.com/doi/abs/10.1177/0361198118797827	Maryland Department of Transportation (MDOT)	Approach to selecting corridors for dedicated bus lanes and other transit priority treatments.	Case Study
Red Colored Transit-Only Lanes Request to Experiment https://www.sfmta.com/sites/default/files/reports/2017/Red%20Transit%20Lanes%20Final%20Evaluation%20Report%202-10-2017.pdf	San Francisco Municipal Transportation Agency (SFMTA)	Example request to experiment used by San Francisco Municipal Transportation Agency (SFMTA) to propose experimenting with red colored transit-only lanes.	Case Study
Report on the Efficacy of Red Bus Lanes as A Traffic Control Device http://stb-wp.s3.amazonaws.com/wp-content/uploads/2014/10/Summary-Red-Lane-Efficacy-Report-to-FHWA-v3.pdf	New York City Department of Transportation (NYCDOT)	This report also includes a brief summary of an additional study by NYCDOT and the Pennsylvania State University on the application of red paint to designate transit lanes.	Case Study
Request for Information Regarding Red Bus Lane Treatments in New York City http://www.nyc.gov/html/dot/downloads/pdf/redbuslane_rfi_052710.pdf	New York City Department of Transportation (NYCDOT)	This Request for Information (RFI) has been issued to inform interested parties that the New York City Department of Transportation (DOT) intends to identify a set of best practices for the installation and maintenance of red-colored bus lanes in the City of New York.	Case Study

Document Name	Published By	Description	Document Focus
Shared-Use Bus Priority Lanes on City Streets: Case Studies in Design and Management https://nacto.org/docs/usdg/shared_use_bus_priority_lanes_on_city_streets_agrawal.pdf	Mineta Transportation Institute	Detailed case studies on the bus lane development and management strategies in Los Angeles, London, New York City, Paris, San Francisco, Seoul, and Sydney.	Case Study
Bus Lanes in Downtown Mami http://miamidadetpo.org/library/studies/downtown-miami-bus-lanes-final-report-2015-12.pdf	Miami Dade TPO	This study provides an assessment of existing transportation conditions in the study area for the Miami Downtown Bus Lanes Study and prioritizes potential corridors for transit-supportive improvements. The data provided is intended to provide the framework for the identification and evaluation of potential transit priority treatments in the downtown Miami area.	Decision Making
Transit Corridor Evaluation and Prioritization Framework https://trid.trb.org/view/776956	Transportation Research Board (TRB)	This report presents the evaluation methodology that was developed and used by Hillsborough Area Regional Transit (HART) (Tampa, Florida) to evaluate and prioritize key transit corridors, or Transit Emphasis Corridors (TECs). This methodology is a planning-level tool to verify if specific improvements relating to bus service, preferential treatment, and/or facilities are warranted. Although it requires tailoring, the methodology developed is intended to be applied by any community establishing priority corridors.	Decision Making
Transit Signal Priority Favorability Score: Development and Application in Philadelphia and Mercer County https://www.dvrpc.org/Reports/13033.pdf	Delaware Valley Regional Planning Commission (DVRPC)	Includes set of criteria for scoring transit signal priority (TSP) priorities within the DVRPC region. A set of criteria was compiled to assess likely TSP effectiveness along corridors in Philadelphia based on a review of industry best practices and available data sources.	Decision Making
Bicycle Policy & Design Guidelines Maryland State Highway Administration https://www.roads.maryland.gov/ohd2/bike_policy_and_design_guide.pdf	Maryland Department of Transportation (MDOT) State Highway Administration	Section 2.13 contains guidelines for Shared Bus/Bike lanes in Maryland.	Design Guidelines and Policy Analysis

Document Name	Published By	Description	Document Focus
Bus Priority Treatment Guidelines https://nacto.org/docs/usdg/bus_priority_treatment_guidelines_national_capital_region_trans_planning_board.pdf	Metropolitan Washington Council of Governments (MWCOG)	MWCOG guidebook reviewing guidelines, best practices, as studies, etc..	Design Guidelines and Policy Analysis
Curbside Management Strategies for Improving Transit Reliability https://nacto.org/wp-content/uploads/2017/11/NACTO-Curb-Appeal-Curbside-Management.pdf	National Association of City Transportation Officials (NACTO)	This paper provides examples of how cities have successfully changed curb use to support transit. It is focused on the types of busy, store-lined streets where high-ridership transit lines often struggle with reliability. These key curbside management strategies support reliable transit and safer streets in one of two ways: either by directly making room for transit, or supporting transit projects by better managing the many demands on the urban curb.	Design Guidelines and Policy Analysis
Designing Bus Rapid Transit Running Ways (APTA 2010) https://www.apta.com/resources/standards/Documents/APTA-BTS-BRT-RP-003-10.pdf	American Public Transportation Association (APTA)	Provides guidance on the design of running ways for bus rapid transit services, including bus lanes.	Design Guidelines and Policy Analysis
Enhanced Transit Corridors Plan Capital/Operational Toolbox https://www.portlandoregon.gov/transportation/article/640269	Portland Bureau of Transit	Design guidelines developed by the Portland Bureau of Transit.	Design Guidelines and Policy Analysis
Guide for Geometric Design of Transit Facilities on Highways and Streets (Chapter 4-2) (2014) https://downloads.transportation.org/TVF-1%20for%20SCOH%20Ballot/TVF-1%20Ch%204-7.pdf	American Association of State Highway and Transportation Officials (AASHTO)	Provides guidelines for dedicated transit lanes on highways and streets.	Design Guidelines and Policy Analysis
King County Metro: Transit Speed and Reliability Guidelines and Strategies https://kingcounty.gov/~/media/depts/transportation/metro/about/planning/speed-reliability-toolbox.pdf	King County	The Speed and Reliability Guidelines and Strategies is a guidance document that King County Metro (Metro), local jurisdictions, and other stakeholders can reference to improve the speed and reliability of transit service together.	Design Guidelines and Policy Analysis

Document Name	Published By	Description	Document Focus
Manual on Uniform Traffic Control Devices (FHWA 2009) https://mutcd.fhwa.dot.gov/	U.S. Department of Transportation	Discusses bus lane signs and pavement markings in chapters Chapter 2G and 3D.	Design Guidelines and Policy Analysis
Saint Paul Street Design Manual: Shared Bus/Bike Lanes (p.75) https://www.stpaul.gov/sites/default/files/Media%20Root/Planning%20%26%20Economic%20Development/Street%20Design%20Manual%20Final101416.pdf	City of St. Paul	Design manual that includes description, recommendations, design considerations for shared bus-bike lanes.	Design Guidelines and Policy Analysis
Shared-Use Bus Priority Lanes on City Streets: Approaches to Access and Enforcement https://www.nctr.usf.edu/wp-content/uploads/2013/12/jpt16.4_Agrawal.pdf	Journal of Public Transportation, Vol. 16, No. 4, 2013	This paper examines policies and strategies governing the operations of bus lanes in major congested urban centers where the bus lanes do not completely exclude other uses. The two key questions addressed are: 1. What is the scope of the priority use granted to buses? When is bus priority in effect, and what other users may share the lanes during these times? 2. How are the lanes enforced?	Design Guidelines and Policy Analysis
TCRP Legal Research Digest 42: Transit Agency Intergovernmental Agreements: Common Issues and Solutions http://www.trb.org/Publications/Blurbs/168256.aspx	Transportation Research Board (TRB)	Framework and guidance for intergovernmental agreements	Design Guidelines and Policy Analysis
TCRP Report 165: Transit Capacity and Quality of Service Manual, 3rd Edition http://www.trb.org/Main/Blurbs/169437.aspx	Transportation Research Board (TRB)	Contains methods for estimating bus speeds on on different types of bus lanes in different environments (chapter 6).	Design Guidelines and Policy Analysis

Document Name	Published By	Description	Document Focus
TCRP Report 183: A Guidebook on Transit-Supportive Roadway Strategies (2016) https://www.nap.edu/download/21929	Transportation Research Board (TRB)	TCRP Report 183 is a resource for transit and roadway agency staff seeking to improve bus speed and reliability on surface streets while addressing the needs of other roadway users, including motorists, bicyclists, and pedestrians.	Design Guidelines and Policy Analysis
Transit and Bicycle Integration: 3.4 Shared Bus-Bicycle Lanes http://www.bettermarketstreetsf.org/docs/BMS_P2-3_BestPractices_12072011.pdf	San Francisco Better Market Street project	Best practices, case studies for shared bus-bike lanes (includes case studies from US and international cities)	Design Guidelines and Policy Analysis
Transit Street Design Guide: Transit Lanes & Transitways https://nacto.org/publication/transit-street-design-guide/transit-lanes-transitways/transit-lanes/	National Association of City Transportation Officials (NACTO)	Overview, analysis, considerations, and design guidelines for various types of transit lanes, transitways, including shared bus bike lanes.	Design Guidelines and Policy Analysis
Primer on Transit Lane Conspicuity through Surface Treatment https://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/primer-transit-conspicuity2010.pdf	Transportation Association of Canada	Recommendations on surface material and installation practices around red lanes.	Design Guidelines and Policy Recommendations
Surface Transportation Optimization and Bus Priority Measures in the City of Boston Context https://www.abettercity.org/docs/Surface%20Transportation%20Optimization%20and%20Bus%20Priority%20Measures%20Final.pdf	A Better City	This report presents the results of the research conducted for the Boston Surface Transportation Optimization Pilot Study, which researched bus optimization measures to determine the current best practices employed domestically and internationally to improve bus operations. Based on this research, VHB developed a list of candidate measures that could be applied to improve travel times and reliability for buses operating in Boston.	Design Guidelines and Policy Recommendations

Document Name	Published By	Description	Document Focus
The identification and management of bus priority schemes: A study of international experiences and best practice https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/centre-for-transport-studies/rtsc/The-Identification-and-Management-of-Bus-Priority-Schemes---RTSC-April-2017_ISBN-978-1-5262-0693-0.pdf	Imperial College London	Study identifies through surveys and interviews how bus priority systems are identified and managed. 14 global cities are reviewed, including cities in Asia, Australia, Europe and North America.	Design Guidelines and Policy Recommendations
Bus Lane Enforcement Study	Metropolitan Washington Council of Governments (MWCOG)	Guidelines around enforcement of bus lanes.	Enforcement Best Practices
A Summary of Design, Policies and Operational Characteristics for Shared Bicycle/Bus Lanes https://nacto.org/docs/usdg/summary_design_policies_and_operational_characteristics_bus_lanes_hillsman.pdf	Florida Department of Transportation (FDOT)	Report investigates design and operation of shared bicycle/bus lanes in municipalities in the US and internationally. Includes recommendations for Florida.	Research/ Synthesis
Bus Lanes with Intermittent Priority: Assessment and Design https://nacto.org/docs/usdg/bus_lanes_with_intermittent_priority_eichler.pdf	University of California, Berkeley (Masters Thesis)	Bus Lanes with Intermittent Priority (BLIP) provide a compromise between dedicated bus lanes and buses operating in mixed traffic lanes.	Research/ Synthesis
Effect of Transit Preferential Treatments on Vehicle Travel Time http://docs.trb.org/prp/16-1724.pdf	Transportation Research Board (TRB)	Study used VISSIM to evaluate benefits of TSP, queue jumps, and bypass lanes.	Research/ Synthesis

Document Name	Published By	Description	Document Focus
Operational Analysis of Bus Lanes on Arterials http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_26-a.pdf	Transportation Research Board (TRB)	This research analyzes the operation of buses along arterial street bus lanes, focusing on operating conditions in which buses have full or partial use of adjacent lanes, exploring the impacts of adjacent lanes on bus speeds and capacities, and deriving relationships and procedures for these impacts and interactions. The research demonstrates how increasing bus volumes can reduce speeds and how right turns from or across bus lanes can affect bus flow.	Research/ Synthesis
Planning for Dedicated Bus Lanes on Roads Carrying Highly Heterogeneous Traffic https://ageconsearch.umn.edu/bitstream/207621/2/2009_53_DedicatedBusLanes_paper.pdf	University of Minnesota	This paper is concerned with modification and validation of a recently developed micro simulation model of heterogeneous traffic flow and application of the model to study the impact of provision of reserved bus lanes on urban roads.	Research/ Synthesis
Red Lane Treatment Analysis https://nacto.org/docs/usdg/red_bus_lane_evaluation_carry.pdf	New York City Department of Transportation (NYCDOT)	This paper presents the methodologies and findings from a series of field and laboratory tests used to evaluate red bus lane treatments for NYCDOT.	Research/ Synthesis
TCRP Report 118 Bus Rapid Transit Practitioner's Guide https://nacto.org/docs/usdg/tcrp118brt_practitioners_kittleson.pdf	Transportation Research Board (TRB)	TCRP practitioners guide includes best practices, case studies, cost estimates, etc..	Research/ Synthesis
TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic (2010) https://nacto.org/docs/usdg/tcrp_synthesis_83_danaher.pdf	Transportation Research Board (TRB)	This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.	Research/ Synthesis
Transit Signal Priority (TSP): A Planning and Implementation Handbook https://nacto.org/docs/usdg/transit_signal_priority_handbook_smith.pdf	Gannett Fleming, Inc/USDOT	TSP technical guidance, good references to other sources.	Research/ Synthesis

Document Name	Published By	Description	Document Focus
Urban Transit Priority Corridors: A Rapid Red Lane to Benefits http://docs.trb.org/prp/16-6237.pdf	Transportation Research Board (TRB)	This paper examines the benefits and costs of a proposed 2.2-mile transit priority corridor in San Francisco. The corridor includes transit only lanes, transit priority signals, and bus stop and pedestrian improvements.	Research/ Synthesis