TRAFFIC ANALYSIS AND INTERSECTION CONSIDERATIONS TO INFORM BIKEWAY SELECTION

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Raleigh, NC 27606
Toole Design Group, 8484 Georgia Avenue, Suite 800
Silver Spring, MD 20910</td><td>8. PERFORMING ORGANIZATION REPORT NUMBER
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Project Manager, Office of Safety
Federal Highway Administration
1200 New Jersey Avenue SE
Washington DC 20590</td><td>10. SPONSORING/MONITORING AGENCY REPORT NUMBER
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This resource supplements the Federal Highway Administration's (FHWA) Bikeway Selection Guide and is intended to inform trade-off decisions associated with bikeway selection at intersections. It discusses common performance metrics, spatial needs of bikeways at intersections, safety and equity focused design principles, and operational traffic analysis trade-offs and assumptions.</td></tr>
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NOTICE

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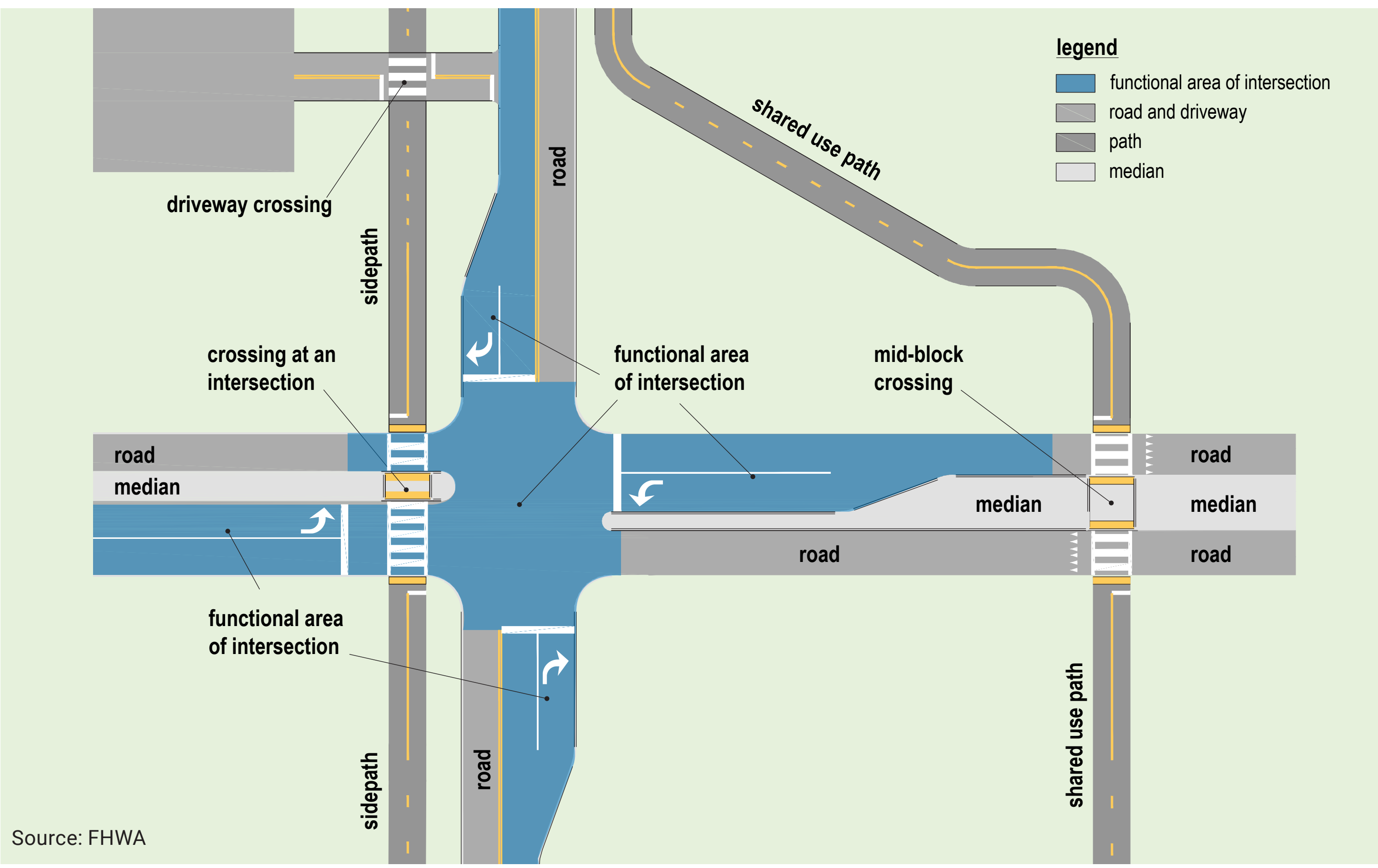
Introduction

Decisions made about the design and operation of street intersections have historically played a central role in the bikeway selection process because these decisions have often been based primarily on favoring motor vehicle traffic. Selecting a bikeway facility that increases safety and aligns with community goals can be challenging when agencies are attempting to reallocate existing space to and through intersections for bicyclists without impacting motorists and other existing intersection users. This resource supplements the Federal Highway Administration's (FHWA) Bikeway Selection Guide and is intended to inform mobility, safety, equity, and policy trade-off decisions associated with bikeway selection at intersections.

This document also supplements other resources including those from FHWA, American Association of State Highway and Transportation Officials (AASHTO), the National Association of City Transportation Officials (NACTO), and the Institute of Transportation Engineers (ITE), which provide detailed design guidance not provided in this document. Design considerations will be noted with references provided to these resources as appropriate.

The consideration of traffic impacts is central to the bikeway selection decision because in many locations existing property lines; existing curbs, drainage, and utilities; and in some communities, buildings, constrain what can be done within the right-of-way (ROW). Expanding right-of-way can be especially costly where it is necessary to modify these typical features. Designers need to ensure retrofits preserve or enhance pedestrian accessibility. They should also be aware that changes on one intersection leg can affect the width of

Figure 1: Crossing Locations Relative to Intersection Functional Area.



the entire intersection, as well as the width approaching the intersection—described as the intersection's functional area (see Figure 1). The functional area of an intersection as defined in the AASHTO "A Policy on the Geometric Design of Highways and Streets" extends both upstream and downstream from the physical intersection area and includes any auxiliary lanes and their associated channelization where vehicles routinely queue at the intersection.

This document includes the following sections:

- **Performance Metrics** should be used to guide decision making and inform trade-off evaluation.
- **Spatial Needs by Bikeway Intersection Type** are a building block for considering bikeway safety and comfort benefits.
- **Safety and Equity Focused Design Principles** set the foundation for the planning and design of a transportation system that is safe and equitable for all users. This section builds on the intersection performance characteristics by bikeway type that are highlighted in the Bikeway Selection Guide (pp. 16-17) based on Sustainable Safety principals.
- **Traffic Analysis Assumptions and Analysis Tips** are provided to establish a basic understanding of standard traffic analyses approaches and their associated inputs. A general overview of this information provides common ground for future trade-off conversations when considering a project that changes the existing roadway and intersection operation schemes.

Performance Metrics

To assess intersection and bikeway design alternatives, performance metrics need to be established. The most common performance metric used is vehicular Level of Service (LOS), which is derived from either vehicular delay or the volume to capacity ratio (v/c) based on Transportation Research Board (TRB) Highway Capacity Manual (HCM) methodologies. In the past, these two measures have often been the primary or only metrics considered in the analysis of intersections. However, the HCM contains guidance discouraging a narrow focused approach, stating that, "(n)either LOS nor any other single performance measure tells the full story of roadway performance."

When vehicular LOS is relied on in isolation, potential negative impacts on vehicular operations are given undue weight and are not balanced against potential impacts on other roadway users, for example relating to accessibility and benefits associated with the installation of a bikeway. To minimize impacts on motorists as measured through LOS, a common strategy has been to downgrade the quality of a bikeway to a lesser facility or to terminate a bikeway through an intersection to maintain or provide additional vehicular capacity to meet an arbitrary LOS criterion. When this happens project and community goals such as increased bicyclist safety, increased bicycle mode share, and bicycle network connectivity are compromised.

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At the outset of a project process that will include intersection design alternatives analysis, it is vital that performance measures are established to reflect the goals of the project and the community, as well as adopted policies. Motor vehicle level of service cannot serve this purpose alone. There are many performance metrics relevant to community goals and agency policies that are generally applied at the facility or small-area level such as bicycle network connectivity, mode shift targets, livability, and climate change impact. The NACTO Urban Street Design Guide and the FHWA Guidebook for Developing Pedestrian and Bicycle Performance Measures are helpful resources to review when establishing performance metrics. Accessibility for pedestrians with disabilities and pedestrian safety in general should always be included in performance metrics discussions. The following are common performance metrics relevant to intersection analysis that should also be considered during bikeway selection and in general intersection design:

Safety

Safety should be a priority focus of the design selection process. The chosen performance metrics can include an assessment of the safety of the design alternatives compared to the baseline condition for bicyclists, pedestrians and other roadway users. In contexts where extensive analytical resources are available, historical crash data, crash modification factors, and safety performance functions can be used to quantify the safety impact of various design choices using methods such as those outlined in the AASHTO Highway Safety Manual (HSM). However, as discussed in NCHRP 926 "...this method should be used with caution, as there are factors... that may increase or decrease the expected number of bicycle crashes that are not considered by the HSM method. Future updates to the HSM are expected to improve methods for estimating the number of bicycle and pedestrian crashes[1]. The Pedestrian and Bicycle Intersection Safety Indices developed by the Pedestrian and Bicycle Information Center (PBIC) may be additional metrics to consider to conduct a quantitative safety analysis. In contexts where a detailed quantitative level of analysis is not feasible, safety can be more qualitatively assessed based on the Sustainable Safety Principals outlined in the Bikeway Selection Guide and discussed below.

For additional information on safety related metrics, consult the following resources:

- AASHTO Highway Safety Manual
- Crash Modification Clearinghouse (http://www.cmfclearinghouse.org/)
- NCHRP 926 - Guidance to Improve Pedestrian and Bicyclist Safety at Intersections (2020)
- NCHRP 948 - Guide for Pedestrian and Bicycle Safety at Alternative Intersections and Interchanges (Pending)
- Pedestrian and Bicyclist Intersection Safety Indices: User Guide (2007) https://www.fhwa.dot.gov/publications/research/safety/pedbike/06130/06130.pdf

Accessibility for Pedestrians with Disabilities

Projects accommodating pedestrian/bicycle traffic need to consider accessibility for all individuals, including persons with disabilities, under Section 504 of the Rehabilitation Act of 1973 (Section 504) (29 U.S.C. 794) and Title II of the Americans with Disabilities Act of 1990 (ADA) (42 U.S.C. 12131-12164), along with USDOT's Section 504 regulations at 49 CFR Part 27 and the US Department of Justice's (USDOJ) ADA Title II regulations at 28 CFR Part 35.

The ADA requires that a public entity's newly constructed facilities be made accessible to and usable by individuals with disabilities to the extent that it is not structurally impracticable to do so. See 28 CFR 35.151(a). The ADA also requires that, when an existing facility is altered, the altered facility be made accessible to and usable by individuals with disabilities to the maximum extent feasible. See 28 CFR 35.151(b). Determination of whether a given design is accessible per ADA, or whether it

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1 Highway Research Program; Transportation Research Board; National Academies of Sciences, Engineering, and Medicine National Academies of Sciences, Engineering, and Medicine 2020. Guidance to Improve Pedestrian and Bicyclist Safety at Intersections. Washington, DC: The National Academies Press. https://www.nap.edu/catalog/25808/guidance-to-improve-pedestrian-and-bicyclist-safety-at-intersections, pgs 39-40

improves existing accessibility for pedestrians in general as well as those with disabilities should be included as a primary screening metric. Separated bikeways and shared use paths will require pedestrian accommodation.

Pedestrian and Bike Quality of Service Metrics

There are several measures that have been developed to reflect the level of stress or comfort experienced by a pedestrian or bicyclist using a facility. These measures include Level of Traffic Stress[2] (LTS) or Bicycle and Pedestrian Environmental Quality Indices[3]. Additional metrics such as Bicycle and Pedestrian Level of Service (BLOS and PLOS) combine user comfort, capacity, and street characteristics and are included in the HCM 2010 Multi-Modal Level of Service (MMLOS) approach. Similar metrics developed by local jurisdictions may also be relevant and follow similar procedures. Each of these measures has some strengths and weaknesses which should be understood before use. For example, BLOS has been statistically validated, but the separated bike lane facility type was not included in the original analysis. LTS can be used to provide a comparison between all bikeway types, but was developed based on expert review.

For additional information on various Quality of Service metrics, consult the following resources:

- Highway Capacity Manual, 2010
- Mineta Transportation Institute: Report 11-19 – Low-Street Bicycling and Network Connectivity[2]
- FHWA Guidebook for Developing Pedestrian and Bicycle Performance Measures

Traffic Analysis

While not suitable as a sole measure of intersection operations because it only assesses motorists delay and capacity, this metric can be illustrative for fine-tuning intersection design choices such as determining lane use allocation where right-of-way is available for more than one vehicular approach lane, testing phasing choices, or proposed signal timing splits. It is also helpful in revealing locations where excess capacity already exists, indicating a road diet or right-of-way reallocation may have limited impacts to motorists. Care should be taken when considering LOS impacts that vehicular impacts at a single intersection do not unduly influence design choices for an entire corridor, or for all modes. Vehicular delay can be calculated using either the deterministic methodologies in the HCM, or by using microsimulation modeling as appropriate. Pedestrian and bicyclist delay should be calculated for comparison and to ensure modal balance is considered at intersections. For example, a common strategy to improve the LOS results in a traffic model is to eliminate a pedestrian crossing, requiring a pedestrian in some instances to make 3 separate road crossings to cross a street, which can significantly increase their delay and exposure to conflicts with motorists. For guidance on the best approach for a given facility, consider the FHWA Traffic Analysis Toolbox[4] or relevant local guidance such as Virginia DOT's Traffic Operations and Safety Analysis Manual[5] or Oregon DOT's Analysis Procedures Manual[6]

Travel Time

Travel time is similar to vehicular delay in that reduced vehicle capacity will be reflected in an impact on travel time; however, travel time provides a wider view of impacts across a corridor. As outlined in the FHWA Guidebook for Developing Pedestrian and Bicycle Performance Measures, "The traditional focus on intersection vehicle delay as a performance measure tends to exaggerate the severity of congestion. For example, an intersection with average vehicle delay greater than 80 seconds is said to have LOS "F" and is 150% more delay than a driver might expect at a LOS "C" intersection. But that intersection likely only represents one point along a trip. Using a typical vehicle trip, that same increase in delay might represent a difference of 45 seconds in a 10-minute trip. Framed in this context, decision makers and community members might think differently about alternatives. Reducing the delay may still be desirable, but consideration should be given to the investment required to reduce the delay relative to overall benefits. This can be a productive way to frame traffic impacts related to bicycle and pedestrian projects." Travel time can also be measured across modes, with average travel time measured by mode, and then generalized to a corridor average travel time per person. This metric is less useful for spot improvement projects or short segments.[7]

As mentioned above, this is only a sampling of potential performance metrics, and accessibility for pedestrians with disabilities and pedestrian safety in general should always be considered. Appropriate metrics for a given project will vary based on the project goals, project context, the design options under consideration, along with the available data, and should be considered in detail for each project. Although the term Level

2 Mekuria, M.C., P.G. Furth, and H. Nixon. Low-Stress Bicycling and Network Connectivity. MTI Report 11-19. Mineta Transportation Institute, San Jose State University, San Jose, CA, 2012.

3 https://trid.trb.org/view/1326355

4 https://ops.fhwa.dot.gov/trafficanalysistools/index.htm

5 http://www.virginiadot.org/business/resources/TOSAM.pdf

6 https://www.oregon.gov/odot/Planning/Pages/APM.aspx

7 FHWA, 2016 Guidebook for Developing Pedestrian and Bicycle Performance Measures, https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/performance_measures_guidebook/ pg 47

of Service (LOS) implies similarity to the vehicular intersection delay rating system established in the Highway Capacity Manual, Bicycle LOS evaluates bicyclists' perceived safety and comfort with respect to motor vehicle traffic while traveling in a roadway corridor. It does not measure delay and is not calibrated to assess the comfort of a separated bike lane. Level of Traffic Stress (LTS) was created to address deficiencies in the Bicycle LOS method such as evaluating separated bike lanes. Ultimately, a blend of performance metrics must be chosen and considered together in order to provide a full picture of the roadway operations.

Spatial Needs By Bikeway Intersection Type

In general, the bikeway type selected for midblock locations should be consistent and continuous through intersections. Allocating space at intersections to provide a bikeway and introducing design elements to limit bicyclist's exposure and increase overall safety are critical objectives in the bikeway selection process. A clear understanding of a bikeway's spatial requirements within an intersection's functional area is critical to inform trade-off discussions.

Figure 2 shows how different bikeway types approach and cross intersections. Each of these bikeway types at intersections have several permutations and allow for variability in dimensions. Practitioners should always consider accessibility and keep in mind that intersections are often a preferred location for a bikeway to transition from one bikeway type to another.

Safety and Equity Focused Design Principles

Intersection design should prioritize accessibility, safety and equity for all users. Although intersections increase conflict points and exposure for pedestrians and bicyclists, adopting a framework that prioritizes safety and equity to design and implement multimodal intersections can reduce conflict severity and frequency. The following design principles reflect the Sustainable Safety Principles noted in the intersection performance characteristics from the Bikeway Selection Guide (pp. 8-9). These should be referenced when planning for and selecting a bikeway type and designing treatments and interventions at intersections. Table 1 highlights additional sustainable safety considerations for bikeway types at intersections.

- **Bikeway Continuity** – Bikeways should not be terminated at intersections. They should continue through them and maintain the same or higher level of protection/comfort as approaching midblock bikeways. An equitable transportation system will ensure the safety and mobility needs of bicyclists are given equal consideration to motorists when evaluating spatial and operational tradeoffs that may impact the ability of a bikeway to be continued through an intersection.
- **Minimize exposure to conflicts** – Bicyclist exposure to conflicts with motorized traffic and pedestrians should be minimized. Exposure risk can rise as traffic volumes and operating speeds increase depending upon the bikeway provided. Exposure to conflicts can be eliminated using a variety of strategies; however, these strategies must be balanced against creating excessive delay or detour for each mode of travel as this may degrade compliance with traffic control devices or yielding behaviors.
- **Reduce speeds at conflict points** - If conflict points cannot be eliminated, intersection design should minimize the speed differential between users at the points where travel movements intersect. This allows users more time to react to avoid a crash and can reduce the severity of a potential injury if a crash does occur. Intersections where bicyclists operate should be designed to ensure slow-speed turning vehicular movements (10 mph or less) and weaving movements (20 mph or less) across the path of bicyclists. Design should also consider interventions to slow bicyclists speeds where they conflict with pedestrian walkways. Common countermeasures may include curb extensions/bulb outs, hardened centerlines, truck aprons, or protected intersections.
- **Clearly communicate right-of-way** – Traffic control devices should clearly communicate which users have the right-of-way at the intersection, including between pedestrians and bicyclists. Intersection geometry and operating speeds should support the desired yielding behavior. Common countermeasures may include crosswalks, regulatory signs, or bike signals.
- **Provide adequate sight distances** - It is necessary to provide adequate sight distances and visibility between bicyclists, motorists, and pedestrians within the intersection and as they approach intersections. Common countermeasures may include curb extensions/bulb outs, parking restrictions, protected intersections, or warning signs.

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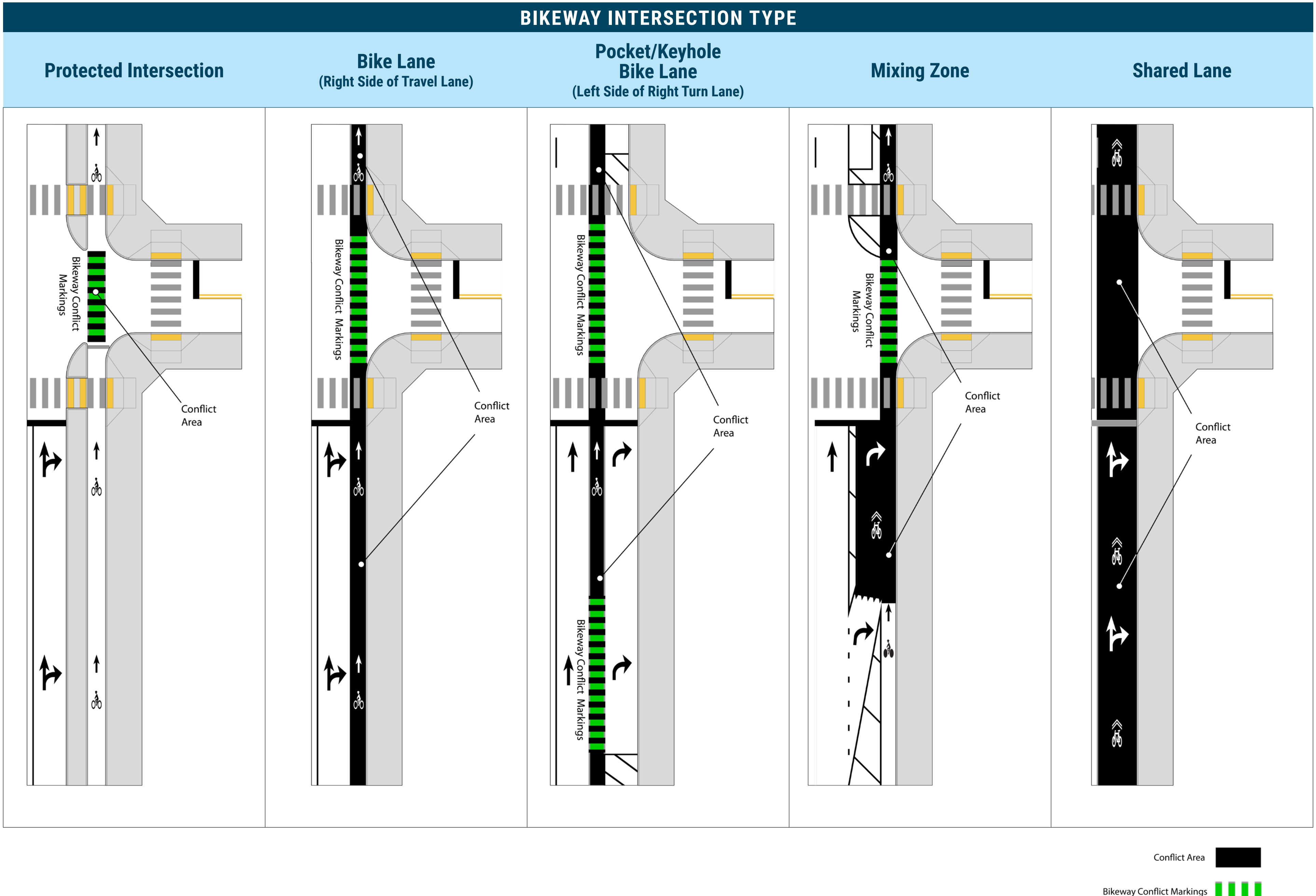
Figure 2: Bikeway Types at Intersections



Source: FHWA

Table 1: Sustainable Safety Considerations for Bikeway Intersection Types

	BIKEWAY INTERSECTION TYPE				
	Protected Intersection	**Bike Lane** (Right Side of Travel Lane)	**Pocket/Keyhole Bike Lane** (Left Side of Right Turn Lane)	**Mixing Zone**	**Shared Lane**
Spatial Considerations					
Bikeway Width	One-way separated bike lane: 6.5'-8.5' Two-way separated bike lane: 10'-12' Shared Use Path: 10'-14'	Bike Lane: 4'-7'	Bike Lane: 4'-7'	One-way separated bike lane approach: 6.5'-8.5' Bike Lane approach: 4'-7'	No designated facility
Street Buffer Width	6'-16'	2'-4' (applicable for buffered bike lane)	2'-4' (applicable for buffered bike lanes)	2'-6' (applicable for approach to the mixing zone for separated bike lanes or buffered bike lanes)	N/A
Length of Approach Exposure	None	None*	Sum of pocket/keyhole bike lane and merge area*	Constrained to merge Area	Unconstrained
Functionality (Comfort) - Roads can be categorized by their function					
Perceived comfort based on separation from traffic and constrained entry/conflict point	High	High to Moderate	Moderate to Low	Moderate to Low	Low
Homogeneity - Roads with vehicles of balanced speeds, directions, and masses are the safest					
Intersection approach exposure to potential motorist conflict	Eliminated	Moderate to High	Moderate to High	Moderate to High	High
Conflict exposure (turning and angle) result generally based upon vehicle speed/volume at intersection	Low to Moderate	Moderate to High	Moderate to High	High	High

* Exposure for users in bike lanes and buffered bike lanes—defined by the lack of vertical separation—along intersection approach is dependent upon vehicle encroachment.

Table 1 (continued)

	BIKEWAY INTERSECTION TYPE				
	Protected Intersection	**Bike Lane** (Right Side of Travel Lane)	**Pocket/Keyhole Bike Lane** (Left Side of Right Turn Lane)	**Mixing Zone**	**Shared Lane**
Predictability (Right-of-Way) - Roads should be intuitive					
Ability to limit or constrain conflicts along bikeway facility	High	Moderate	Moderate to Low	Moderate to Low	Low
Right-of-way priority between motorists and bicyclists is clarified through the intersection	High**	High to Moderate	Moderate	Low	Low
Forgiveness (Safety) - Infrastructure can be designed to accommodate human error					
Relies upon highly aware motorist and bicyclist behavior to avoid crashes	No	Yes	Yes	Yes	Yes
Bicyclists operate in separated space from vehicles	Yes	Yes, however vehicles can encroach into the facility at any location	Yes, however vehicles can encroach into the facility at any location	Yes, prior to mixing zone; however, vehicles may encroach into facility if it is not separated	No
Awareness (Visibility) - Awareness improves safety for all users					
Level of motorists/bicyclists scanning required to identify bicyclists, and/or motorists approaching from behind or operating beside them	Low to Moderate	High	High	High	High

** Protected intersections require careful design to ensure clear right-of-way between bicyclists and pedestrians and people with disabilities are fully accommodated.

Traffic Analysis Assumptions and Analysis Tips

While some jurisdictions make decisions without traffic analysis, most require it to document the changes to the function of a street or intersection due to planned reconfiguration or design changes. Conventional traffic engineering has historically relied solely on motor vehicle analysis of peak hour operations to make transportation decisions. In many communities, this approach has led to streets and intersections that are often overbuilt and don't support community goals. It is essential that practitioners think critically about traffic analysis assumptions and analysis approaches and evaluate how these choices influence the analysis outcomes and what is ultimately built. Rather than allowing a motor vehicle-focused analysis to dictate decisions, jurisdictions can use traffic analysis to inform the development of a transportation environment that the community wants – a place that supports economic development, allows people to walk and bike to destinations and supports transit use where those goals (or others) are desired. The sections below provide background on conventional analysis practices and the challenges and consequences associated with these practices as they relate to bikeway selection, and discusses how practitioners and agencies can adjust their assumptions and methodologies to fit within a holistic approach.

Volume Projections

A common practice in traffic engineering is to use a "conservative" approach to estimate traffic volumes (i.e. higher traffic volumes) in an attempt to maximize capacity and minimize delay for motorists over the lifespan of a facility. While a conservative approach is appropriate and necessary in other types of engineering, like structural design, this approach in traffic analysis has led to street and intersection designs that favor motor vehicles, often resulting in undesirable outcomes: expensive construction projects with increased long term maintenance costs, higher crash rates, streets with excess motor vehicle capacity, and intersections that do not support economic activity or accommodate people walking and biking.

Future Year

Traffic analyses often study a future condition 5 to 30 years in the future. Conventional traffic analysis often focuses on this future year condition to identify improvements to ensure that the street or intersection will function well for motorists in that future year. A challenge with this approach is that it can result in streets that are overbuilt for the current condition, which can reduce the safety performance of the roadway until such time as that future traffic conditions are realized. This approach also presumes that existing travel behaviors will remain the same forever and this can become a self-fulfilling prophecy, which can undermine community mode split goals. In situations where traffic increases are not realized, agencies will have increased their maintenance liability without realizing any benefits. Rather than letting this distant future year dictate decisions that are made, this future year should be evaluated as one of many scenarios for reference during the decision-making process.

Growth Rates

Motor vehicle traffic volume projections typically include a growth rate. The growth rate increases motor vehicle traffic volumes based on trends in historic annual average daily traffic (AADT) numbers, regional travel demand modeling, or an accepted agency practice of an assumed specific percentage growth per year (e.g. a growth rate of 2% per year). These approaches assume there will be more vehicle volume eventually even in locations where historic traffic trends are flat or declining. In locations where there has been an upward trend in traffic volumes, these approaches often assume past behavior will be indicative of future behavior even though modal shifts may occur due to changes in land use, expansion of multi-modal transportation networks, or transportation policies. Regional travel demand models are often deemed "conservative" and are also calibrated based on present or past travel patterns and demographics and may not adequately capture changes such as shifts in mode choice due to future unanticipated changes in the network[8] or reflect community desires about mode share goals. It is recommended growth rates align with long term community transportation goals.

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8 Parthasarathi, P., Levinson, D., Post-construction evaluation of traffic forecast accuracy. Transport Policy (2010), doi:10.1016/j.tranpol.2010.04.010

Trip Generation

Trip generation tables exist to provide information for a wide range of development activities. These estimates are often based on largely suburban model trip generation rates and pre-internet retail use patterns, which have been proven to overestimate trips. The ITE Trip Generation Manual has expanded methodologies for trip generation in different contexts. Additional tools such as the Environmental Protection Agency's (EPA) Mixed-Use Trip Generation Model can also provide useful trip generation information. Trip generation estimation is an art rather than a science that requires practitioners to evaluate the data available and determine whether it is appropriate for the context of their project. Specifically, practitioners should consider typical mode splits for the locality (i.e. use local mode split data if available), community goals for mode splits, and the likelihood of trips to calculate estimated trips. Much like the scenarios suggested in the discussion above about future year, practitioners could consider analysis with different trip generation scenarios to provide a range of results for consideration.

KEY TAKEAWAY Streets and intersections that are designed for "conservative" motor vehicle volume forecasts often result in overbuilt streets, a design that does not meet community goals (e.g. safety) and are economically wasteful. Practitioners should estimate volume projections that are realistic and consistent with project or community goals for mode share.

ANALYSIS TIP: Conduct analysis of multiple volume scenarios that provide a range of results to inform decisions rather than using one future volume forecast to dictate decisions based on an increase in volume that might not be realized.

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Level of Service[9] (LOS)

Conventional traffic analysis exclusively uses performance measures for motorists like delay, LOS, volume-to-capacity, and queuing. Where this analysis is used to make decisions, the outcome will be a built environment that prioritizes motor vehicles. The Highway Capacity Manual emphasizes that LOS is a part of a bigger picture and "neither LOS nor any other single performance measure tells the full story of roadway performance" (HCM 2016, page 8-12). Practitioners should select performance measures that respond to project goals and present a holistic picture of the street or intersections being studied (see Performance Metrics section for additional details on additional performance measures).

In addition to relying solely on motor vehicle performance measures, conventional traffic analysis focuses on improving LOS, reducing delay, and minimizing queues to levels that are deemed "acceptable". It is essential that practitioners and agency staff are thoughtful in their interpretation of motor vehicle analysis results. As stated in the HCM, ''the existence of a LOS F condition does not, by itself, indicate that action must be taken to correct the condition" (HCM 2016, page 8-21). An agency or jurisdiction should consider allowing higher vehicular delay, higher LOS, and longer queues in the context of other performance measures and project goals.

KEY TAKEAWAY Motor vehicle level of service alone does not fully describe the value and function of a street or intersection that includes all users of the roadway or purposes of the roadway and surrounding landuse. Practitioners should select performance measures that respond to project goals (see Performance Measures section).

ANALYSIS TIPS:

- For motor vehicle queues, evaluate the 50th-percentile queue in addition to the 95th percentile queue.
- When interpreting results, practitioners should consider whether a LOS F (or other conventional standard) may be acceptable during certain peak hours if other project goals are achieved.

Time Period and Analysis Period

Conventional traffic analysis typically uses volumes from a one or several one-hour time period(s) during peak hours (typically AM and PM peak hours of a weekday) to evaluate the movement of the largest traffic volumes. These peak hours are typically taken during a peak period of the week (e.g. Tuesday, Wednesday or Thursday), and year (e.g. when school is in session). Additionally, conventional traffic analysis also often uses a Peak Hour Factor (PHF) to convert hourly volumes

9 https://www.fhwa.dot.gov/design/standards/160506.cfm

to peak 15-minute flow rates, effectively using a 15-minute analysis period. Finally, in some cases, jurisdictions require that PHF for individual approaches or movements are used. This assumes that the peak 15-minutes of each approach overlaps with each other, which may not be the case. All these factors can compound together resulting in volumes that are the peak of the peak being studied, rather than typical or average values. The consequence of these approaches is like those described in the section on volume projections: streets are overbuilt and often don't support community goals. At a minimum, practitioners should collect data outside of the peak hours being studied to understand how the peak hour volumes compare to off peak volumes. This understanding can be helpful when evaluating results and making decisions about the changes to the intersection like turn lanes, maintaining a bike lane through an intersection, separate bike phasing, etc. An alternate approach is to use an average of volumes over a 2-3-hour peak period rather than a single peak hour – this would be an average peak period analysis rather than a peak hour analysis. Practitioners should also consider using a peak hour factor for the intersection rather than for individual movements or approaches.

KEY TAKEAWAY People use streets at all hours of the day and night and the use of street varies throughout the entire day; streets should be designed for all day use, not just a single peak hour (or even peak 15- minutes).

ANALYSIS TIPS:

- Use a peak hour factor based on the entire intersection, not specific movements.
- Collect data for a 2-3-hour peak period at a minimum or, ideally, a 24-hour period to understand the demands of the street throughout the day. Consider averaging 2-3-hour peak to analyze an average peak hour.

Network Utilization/Peak Spreading

When balancing vehicular delay and operations against dedicating additional space to a safer and more comfortable bikeway, a practitioner should consider whether parallel network capacity could accommodate a portion of the existing vehicle traffic. This may include analysis that considers the impact of a change in the network or improvement of an intersection that is "outside the study area" which if built, would help address capacity constraints within the study area. Expanding the study area or gathering origin destination data can help practitioners to understand how the available network could best be used. In cases where a larger study is not feasible, agencies can consider an intersection level sensitivity analysis to understand the level of vehicular traffic that would need to shift to other routes in order to maintain the levels established by performance metrics. The sensitivity analysis could also evaluate the number of vehicles that would need to shift to other time periods (sometimes as little as 15 minutes) or to other modes.

KEY TAKEAWAY When intersection or corridor projects are evaluated in isolation, the broader context of the surrounding network is lost.

ANALYSIS TIP: In locations with constrained right-of-way and congested operations, practitioners should look beyond the defined study area to determine if there are viable alternate routing choices available for motorists. Additionally, there is often additional capacity outside the peak hour being studied where a shift of volumes by even just 15 minutes can provide some relief to motorists.

Signal Timing Assumptions

Green Interval

When the green interval is determined only on the basis of motor vehicle traffic, it may not be sufficient for bicyclists who have longer start-up times and slower travel speeds. This is particularly an issue for larger intersections, intersections that are on steeper grades, or where bicyclists may be queued further back from the intersection. In these locations, the green interval may need to be longer for stopped bicyclists to proceed and clear the intersection before the light changes. Where practitioners are trying to optimize intersection operations, bicycle detection may be used to extend the green interval when bicyclists are present to ensure bicyclists can clear the intersection safely.

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Yellow Change and Red Clearance Intervals

When the yellow change and red clearance intervals are determined only on the basis of motor vehicle traffic, they may not be sufficient for bicyclists who have different braking characteristics or who travel at slower speeds. This is particularly an issue for larger intersections and intersections that are on steeper grades. These intervals may need to be longer to allow a bicyclist who is approaching the intersection at speed near the end of the green interval. If the yellow change and red clearance intervals are too short, the bicyclist may still be traversing the intersection when the conflicting traffic gets a green indication. Where practitioners are trying to optimize the intersection operations, bicycle detection may be used to extend these intervals only when bicyclists are present. The MUTCD says, "The duration of a red clearance interval may be extended from its predetermined value for a given cycle based upon the detection of a vehicle that is predicted to violate the red signal indication."

KEY TAKEAWAY Signal timing parameters may require adjustment to accommodate all users.

ANALYSIS TIPS:

- Practitioners should consider the operating characteristics of the expected user of a facility and adjust assumptions accordingly.
- For signal progression, consider using a lower progression speed when setting signal offsets in order to accommodate more efficient bike travel through a corridor (12-15 mph).

Discussion Prompts

Below are some specific questions to consider during operational analysis in support of bikeway selection at a constrained intersection.

Volume Projections

- Are motor vehicle volume projections realistic or are they considered "conservative"? Do they rely heavily on individual land uses from the ITE Trip Generation Manual?
- What are volume projections based on?
- Are volume projection timelines required or a design decision?
- Do they reflect the mode share and potential mode shift to more people biking with the implementation of a more complete, comfortable bike network?
- Do they reflect the mode share and potential mode shift to more people walking with the implementation of a more complete, comfortable and accessible pedestrian network?
- What are the future mode share goals? How would this intersection function/look if those goals were met?

Level of Service

- Does prioritizing motor vehicle level of service result in either dropping the bikeway or using a mixing zone treatment rather than continuing a high-comfort bikeway through the intersection?
- Can a lower motor vehicle LOS be accepted during the peak hour so that a high-comfort bikeway can be continued through the intersection?
- How sensitive is the LOS to changes in the peak volume? What is the off-peak LOS?
- How will LOS assumptions impact the overall intersection footprint? Achieving desirable motor vehicle LOS in the peak hour may require a larger intersection footprint. This larger footprint results in a less efficient intersection, increases pedestrian crossing distances, especially during off peak hours, and uses land that could otherwise be open space or developed.
- Determine a maximum amount of single occupant vehicle traffic that is desirable and what would be necessary to achieve it to start the process.

Analysis Period

- Does the analysis evaluate the peak 15 minutes for individual intersection approaches, which may not actually occur at the same time in practice? An analysis that assumes a more even distribution of traffic over the hour will be more representative of what a typical driver might experience.
- How long is the peak period? Is this peak period volume desirable and compatible with other goals for this area?
- If pedestrian or bicycle peak periods occur at a different time, consider studying those time periods as well.

Network Utilization/Peak Spreading

- Is there a parallel or alternate route that motorists could use if delay is high at an intersection?
- Is traffic volume data up to date for surrounding streets and intersections to assist with network utilization analysis?
- Are there parallel or alternate route that could accommodate a low-stress bikeway and still provide access to key destinations?
- If a movement or movements are experiencing some delay during the peak hour, is it possible that some of that traffic could shift outside the peak hour, but still within the peak period?

Accessibility

- Can bicyclists and pedestrians cross existing uncontrolled crossings, or is additional traffic control necessary?
- Does the design provide accessibility to all users, particularly people with disabilities, pedestrians and bicyclists of all ages and abilities?

Conclusion

This document is a supplemental resource to help transportation practitioners make informed decisions about the trade-offs in bikeway selection specific to intersections. It focuses on traffic analysis because this often frames and constrains discussions about intersections. It builds upon the guidance in the Bikeway Selection Guide and includes helpful references to specific design and planning guidance.

Intersection related considerations, particularly in locations with limited right-of-way, have the potential to dominate the conversation on bikeway selection, but pedestrian safety, the need to ensure accessibility, and project goals should always be in the forefront of the conversation. This resource presents a broad range of metrics that can be used in design evaluations, and outlines approaches for traffic and operational analysis. It relates this information back to design principals and options for bikeway selection at intersections to encourage holistic decision-making in the planning process as part of systemic safety approach that is tailored to community goals and meets the needs of people of all ages and abilities.

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